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BOARD OF WATER SUPPLY

OF

THE CITY OF NEW YORK

LONG ISLAND SOURCES

Reports, Resolutions, Authorizations, Surveys and Designs Showing Sources and Manner of Obtaining

From Suffolk County, Long Island

AN ADDITIONAL SUPPLY OF WATER

FOR

THE CITY OF NEW YORK

Volume I

New York City

1912

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ILLUSTRATIONS

BOARD OF WATER SUPPLY
CITY OF NEW YORK

The water-supply conditions in Brooklyn became so bad in 1896 that an actual shortage of water was imminent and the Manufacturers' Association of that borough (then a city) appointed a committee to investigate the problem of an additional supply of pure water.

The results of thorough investigation by this committee are revealed in its report of March 15, 1897, wherein the following three principal recommendations appear: That steps be taken to separate the water debt from the constitutional debt limit of the municipality; that a special commission should be appointed to investigate all sources of water-supply for Greater New York; and that plans for ultimate sources for the supply of Greater New York should contemplate a period of not less than fifty years so that the work of construction might be harmonious, intelligent, economical and always in the direction of the final plan.

The Manufacturers' Association after continued investigation and agitation caused bills to be prepared and introduced into the Legislature in 1901, 1902, 1903 and 1904 to carry out the above recommendations which finally resulted in the passage, on June 3, 1905, of the act creating the Board of Water Supply and the appointment of the three Commissioners composing it on June 9, 1905.

Chapter 724 of the Laws of 1905, comprised in this act, states: " It shall be the duty of the Board to proceed immediately, and with all reasonable speed, to ascertain what sources exist and are most available, desirable and best for an additional supply of pure and wholesome water for The City of New York. The Board shall make such surveys, * * * and investigations as it may deem proper * * *."

At a meeting of the Board of Water Supply, held August

8, 1905, following the consideration and adoption of the general plan for getting a supply for the whole City west of the Hudson river, the situation in Brooklyn was discussed and the following resolution, offered by Commissioner Chadwick, was passed:

"Resolved, That the Chief Engineer be and he is hereby authorized and instructed to prepare a special report upon the water situation in Brooklyn, to be submitted to the Board of Water Supply as soon as practicable."

Preliminary studies following the lines of investigation and suggestion of the Burr-Hering-Freeman report of 1903, were soon undertaken and under date of October 9, 1905, the Chief Engineer pointed out the availability of the sources on Long Island for affording quick relief to the needs of Brooklyn, which were more pressing even than the needs of Manhattan.

On May 23, 1906, he recommended that extensive surveys and investigations be made in Suffolk county in order to determine the best plan for developing the water sources there, and also recommended that an opinion be obtained from the Corporation Counsel as to whether the Board had the right to carry on preliminary work in that county (see page 5). The Corporation Counsel rendered an opinion, on July 23, 1906, that the Board was justified in making surveys and investigations in restricted localities and in expending the funds appropriated for the Board on such investigations.

Following this active work was begun and the Long Island department of the Engineering bureau was organized on October 19, 1906, with the appointment of Walter E. Spear, Division Engineer in charge, to investigate the water resources of Suffolk county and means for rendering them available.

As the studies and investigations progressed, reports in detail were submitted by the Chief Engineer on March 15, October 1, and October 9, 1907 (see pages 7, 11 and 16); and on December 4, 1907, a complete outline of the entire work, together with the special studies then nearing completion, was sent to the Board (This report is included in report beginning on page 17).

On May 21, 1908, the Chief Engineer submitted a report with map, plan and profile showing the source and manner of obtaining an initial supply of 70,000,000 gallons of water daily, at an estimated cost of $21,700,000, and a complete development from underground sources of 250,000,000 gallons

daily, at an estimated cost of $40,479,000 to $47,173,000 (see page 17).

On June 8, 1908, the Board of Water Supply forwarded to the Board of Estimate and Apportionment the map, plan and profile of the proposed works and recommended that they be approved and transmitted to the State Water Supply Commission for its approval (see page 27).

On June 12, 1908, the Chief Engineer reported in detail the results of investigations, surveys, studies and plans looking to the development of a supply from Suffolk county and conveying it to the Borough of Brooklyn (see page 30).

The Board of Estimate and Apportionment, after a public hearing approved on June 26, 1908, the plan submitted by the Board of Water Supply and on July 29, 1908, petitioned the State Water Supply Commission for its approval (see page 46), which application is pending at this writing.

It was at the outset considered possible that existing legal restrictions concerning the use of Suffolk County water could be removed within such time as would permit local works to be built and in operation prior to the entry of water from the Catskill Mountain watersheds, and surveys and designs for the immediate development of Suffolk County sources were actively forwarded with that purpose in view.

As the preliminary steps to the lifting of legal obstructions to this plan have been, so far, seriously delayed, it has been decided to bring together and print all of the various papers in this matter so that they may be preserved in permanent form.

CHARLES STRAUSS,
CHARLES N. CHADWICK,
JOHN F. GALVIN,
Commissioners,
Board of Water Supply.

November 1, 1912.

BOARD OF WATER SUPPLY
CITY OF NEW YORK
299 BROADWAY

J. Edward Simmons
Charles N. Chadwick
Charles A. Shaw
Commissioners

J. Waldo Smith
Chief Engineer

New York, May 23, 1906.

Board of Water Supply,
299 Broadway, New York City.

Gentlemen:

In a report submitted to the Commissioners, dated October 7, 1905, the Chief Engineer made the following statement:

"With the legal restrictions and the limitations that surround large construction work for The City of New York, it now appears probable that even with the most vigorous beginning and the most rapid progress, from five to eight years must elapse before water from the new source can be delivered into Croton lake, and thence to Manhattan, Brooklyn and the other boroughs. Although the Boroughs of Manhattan and The Bronx, being more directly on the line of the aqueduct that will end in Brooklyn and Richmond, will, therefore, be naturally the first to be benefited, it must be recognized that the present needs of Brooklyn are even more pressing than the needs of Manhattan, and they have, therefore, already engaged the attention of your Engineers. The water shortage in Brooklyn during the past season is almost without precedent in the history of a large American city."

Your Engineer has constantly in mind the urgent needs of Brooklyn and studies have been progressing in this office and have reached a point where I am prepared to report that there is nothing for this Board to do looking to the alleviation of the present conditions except to obtain water from Suffolk county.

To obtain the best results, this plan must be laid out in a broad, comprehensive way, looking to the development of all the available supply of the region to the east in Suffolk county. In order to determine what this plan should be, extensive

surveys and investigations will be necessary. The question arises whether the Board, in view of the restrictive legislation, has the power under Chapter 724 of the Laws of 1905, as amended, to carry on these extensive preliminary investigations and to present a plan for supplying Brooklyn and to meet a possible shortage of water in Manhattan before the Catskill water can be delivered.

Before a recommendation to repeal existing legislation is made, it is important that a comprehensive plan be outlined which will show clearly the best design of works and will make plain just what The City of New York desires to do. It is important, also, to determine, so far as possible, the basis for the opposition to the taking of this water and to secure by careful investigation full data upon which the reasonableness of The City's request and the objections thereto may be fairly judged or methods sought for meeting such of the objections as may appear well grounded.

I would respectfully suggest to the Board that this matter be taken up with the Corporation Counsel and his opinion requested as to the rights of the Board to perform the preliminary work necessary to prepare a plan for taking water from Suffolk county.

Respectfully submitted,

J. WALDO SMITH,
Chief Engineer.

BOARD OF WATER SUPPLY
CITY OF NEW YORK
ENGINEERING BUREAU
299 BROADWAY

J. Edward Simmons
Charles N. Chadwick
Charles A. Shaw
Commissioners

J. Waldo Smith
Chief Engineer

New York, March 15, 1907.

Board of Water Supply,
299 Broadway, New York City.

Gentlemen:

The following brief report on the progress of the investigations of the Long Island sources, which were begun in October, 1906, is submitted for your information.

The Long Island problems to be solved by these investigations are:

(1) The determination of the amount of ground-water and surface-water available on Long Island for The City of New York.

(2) That of finding the best location for the development of these waters, and the best method and cost of such development.

(3) That of finding the means and probable cost of bringing this water to New York City.

These problems in Suffolk county required:

(A) Complete topographical surveys of the southerly portions of the county where it appeared feasible to make a ground-water development.

(B) Surveys of the surface of the ground-water within the area covered by the topographical surveys and, beyond, over much of the county to complete the work begun by the Burr-Hering-Freeman Commission in 1903. These surveys required the driving of many additional test-wells, by which to determine the surface of the water-table.

(C) Continuous gagings of the flow of all the important streams in Suffolk county.

(D) The testing out of the volume and character of the ground-water resources by sinking and pumping large, deep wells.

A—TOPOGRAPHICAL SURVEYS

The great extent of territory to be covered, from Nassau county to Riverhead (about 50 miles in length and perhaps 3 miles in width) required for control a system of triangulation on which to base an accurate rectangular co-ordinate survey.

One of the first pieces of work that was done in the first part of November was the selection of suitable primary stations for a system of quadrilaterals on high buildings, towers, windmills and other structures. So fortunate was the search for these stations that it has been necessary to build only six towers of any hight. Only one of these remains incompleted because of the delay in securing the lumber.

The triangulation stations of the U. S. Coast Survey were, as far as possible, included in our system. From the geographical position of one of them near Lindenhurst the coordinates of the station were computed from the Prospect Park water-tower in Brooklyn, which is the center of coordinates of the extensive co-ordinate surveys now being carried on by the topographical bureaus of the boroughs of Brooklyn and Queens. The selection of the same center of co-ordinates for our surveys will greatly facilitate the surveys from Suffolk county to Brooklyn and Queens boroughs.

After the selection of the primaries, secondary stations were picked out along the most probable locations for the proposed development, at intervals of a mile or two. These have been cut in from the primary stations and will serve when their co-ordinates are computed as points of beginning for the stadia surveys.

The field work on the primary system is now complete except near Oakdale, where it was necessary to change a primary station, and near Mastic, in the Moriches, where a tower has not yet been built.

The triangulation system from Nassau county to Babylon has been adjusted and the co-ordinates of the primary and secondary stations computed and plotted on standard sheets of mounted white paper on a scale of 200 feet to the inch. An index map covering the whole of Suffolk county, on a scale of 6,000 feet to an inch is being prepared. The results thus far indicate that the accuracy of the primary triangulation work is perhaps 1:40000.

As a basis for the topographical work and the ground-water surveys a line of precise levels was run from the stand-

ard bench-mark of the Brooklyn Water Works at Smith's pond near Rockville Center to Eastport and return, along the Montauk division of the Long Island railroad. From the bench-marks established along this line closed traverses were run into the center and northerly portions of the island east of Babylon and Smithtown and as far as Riverhead. Altogether 258 miles of these levels were run.

This work was done by a bench level party temporarily transferred from the Northern Aqueduct department. The results were very satisfactory; the accuracy as indicated by the value of C in the equation $E = C \sqrt{D}$ (where E = error, D = the distance levelled over) will average 0.013.

Secondary levels are being run in short circuits between the precise bench-marks, for the purpose of establishing additional benches for the stadia work and to determine the elevations of the test-wells for the ground-water surveys.

This secondary level work is well advanced. Except for a stretch of a few miles near Islip, the work now covers pretty much all the territory that it is proposed to survey for the proposed ground-water development.

B—GROUND-WATER SURVEYS

Two-inch test-wells one-half to one mile apart have been driven along the southerly portion of Suffolk county as far as Quogue and at greater intervals over the north of the island east of Patchogue and Port Jefferson.

The wells laid out over this territory have been recently completed, except for a few wells on the grounds of the South Side Sportsmen's Club, where permission to do the work was refused. Altogether 307 wells containing 12,342 linear feet of pipe were driven under agreements with F. W. Miller and Roy S. Barker.

These test-wells and others are being levelled upon in the secondary level work and the basis for a more accurate map of the ground-water surface is being obtained.

C—STREAM GAGING

Permission has been obtained to construct weirs on five important streams and bids have been received for the work.

In the meantime gagings of flow of all the important streams have been carried on by means of a current meter. There have been made altogether 83 of these measurements.

D—TEST-BORING

The California stovepipe well rig is being assembled at Babylon. Much of the material has arrived or is on the way. The expert driller, Mr. George W. Catey, is inspecting all the tools and machinery and the men for his crew have been selected.

Permission to occupy lands remote from habitation near Babylon for the proposed experiments with the stovepipe well is being secured and an alternative location is being looked into near Patchogue.

SUMMARY

Briefly, the triangulation work and the levels are well advanced; the 2-inch test-wells are finished, and the stadia work will be begun the last of March, when the snow has disappeared. These stadia surveys, as well as the proposed California stovepipe wells, will be started along the lines that the preliminary estimates, now being prepared, indicate to be most feasible for the aqueduct and the well locations.

Respectfully submitted,

J. WALDO SMITH,
Chief Engineer.

BOARD OF WATER SUPPLY
CITY OF NEW YORK
ENGINEERING BUREAU
299 BROADWAY

J. Edward Simmons
Charles N. Chadwick
Charles A. Shaw
Commissioners

J. Waldo Smith
Chief Engineer

New York, October 1, 1907.

Board of Water Supply,
299 Broadway, New York City.

Gentlemen:

In accordance with your verbal request, I transmit the following report regarding progress of the work in the Long Island department:

" Since the organization of the work in late October, 1906, we have made topographical surveys of the most probable lines of ground-water development along the south shore of Suffolk county and of the proposed aqueduct from eastern Suffolk county to Ridgewood; gaged continuously the more important Suffolk county streams; driven 2-inch test-wells and made monthly observations by which to determine the surface of the ground-water within the watershed to be drawn upon by the proposed development; and investigated the deep water bearing strata near Babylon by means of large, deep wells of the California stovepipe type.

" In addition to these investigations of the problems of collection and transportation of the Suffolk County waters to New York, we have made preliminary borings and surveys for the proposed pipe crossing in the Narrows, New York Harbor, from Bay Ridge, Brooklyn, to Staten Island, and have reconnoitered and surveyed several sites for distributing reservoirs in Brooklyn borough.

" Field offices have been established at Jamaica, Babylon, Patchogue and Center Moriches.

TOPOGRAPHICAL SURVEYS

" Beginning the first of last November, we established during the winter a system of triangulation from the Nassau-Suf-

folk County line as far as Quogue, tying up to Coast Survey points and covering a strip about five miles in width along the south shore of Long Island.

" Having completed this work of control, we began in May the survey of a location for the proposed ground-water development from Amityville to West Hampton, two to three miles from the salt waters of the south shore bays. The field work of the first line on this location is now completed and mapped, with the exception of half a mile on the grounds of the South Side Sportsmen's Club. Alternate locations are now being run south of the first line and these surveys are all but finished from Amityville to the Carman's river.

" Branch lines into the center of the island in the valleys of the Connetquot brook and Carman's river have been surveyed above the bounds of the Sportsmen's Club and the Suffolk Club. From the end of the main line at West Hampton, we have run about half way to Riverhead on the branch line proposed for the diversion of the Peconic river to the proposed south shore aqueduct.

" In July we placed parties in Nassau county and Queens borough and have since surveyed a location for the proposed aqueduct line from Suffolk county to the Ridgewood pumping-station of the Brooklyn works. The field notes have been worked up and a portion of the line is plotted.

" In brief, we have surveyed one complete line from Ridgewood to West Hampton, 80 miles in length, 18 miles of alternate location near this line, and 10 miles of branch line into the center of the island. To accomplish this work, 155 miles of traverse have been run.

STREAM GAGING

" All important streams in southern Suffolk county and the Peconic river at Calverton are being gaged and the measurements of flow of the Massapequa creek are being continued at the station established in 1903 by the Burr-Hering-Freeman Commission.

" Weirs were erected in May and June on eleven Suffolk County streams and at each a recording gage has since been maintained. At six other streams, where weirs could not be erected, current meter measurements have been carried on. The results of all these measurements have been worked up to the 1st of September.

"In connection with these stream gagings, three rainfall stations were established last year at Babylon, Center Moriches and Lake Ronkonkoma, respectively, to supplement the observations of the U. S. Weather Bureau.

TEST-BORING

"From November, 1906, to February, 1907, 12,342 linear feet of 2-inch test-wells were driven in the southerly portion of Suffolk county from Amityville to Quogue and in the central and northerly portion of the island east of Port Jefferson and Patchogue. These wells were driven to a depth of 30 to 100 feet into the yellow sands and gravels for the purpose of securing samples, defining the surface of the groundwater in this area and determining the ground-water catchment tributary to the development proposed.

"After the location for the proposed aqueduct was defined with greater certainty than was possible at the time of this early work, about 4,500 linear feet of 2-inch test-wells were laid out along the surveyed lines and of this amount about 1,000 feet have now been driven.

"In May of this year we completed the assembling of the California stovepipe rig, the most of which was ordered during the previous November and December. We then began the deep well investigations at the "Babylon experiment station" in West Islip and have now completed two wells there, one 14 inches in diameter, 812 feet deep, and a second 12 inches in diameter and 170 feet in depth. Very nearly two months were lost in July and August awaiting deliveries on stovepipe casing.

"The first of these wells showed no gravel or coarse material from which water could be drawn below a depth of 100 feet. The lower strata appeared to be made up of fine gray sands and clays. The character of the strata at this point having been established, the second of the group of three wells proposed at the experiment station was driven only to a depth of 170 feet, as stated. The third well, 16 inches in diameter, has just been started and will not exceed a depth of 200 feet.

"It is proposed to pump these three stovepipe wells, to determine the delivery of this type of well in the Long Island gravels and the proper spacing of such wells in the proposed final development. Boilers, compressors and generator have been set up at this experiment station in a temporary house erected there. Air-lines have been laid and wooden flumes

constructed by which to discharge the water pumped from the wells beyond the ground-water catchment tributary to them. Two-inch test-wells have been driven about the stovepipe wells in order to study the depressions and movement of the ground-water and the interference of one stovepipe well with another. These wells were driven from 25 to 75 feet in depth and aggregate 4,000 linear feet.

"Studies and mechanical analyses of the sands and gravels found in the stovepipe wells have been made at the experiment station and preparations have been made for the experimental filtration of the ground-waters there for the removal of iron. The iron contents of the waters appears, however, to be small and this work will not probably be carried out.

"Other stovepipe wells have been laid out at intervals of three to five miles along the proposed line of development, beginning at Lindenhurst, where a portable building and casing pipe have already been placed.

"Monthly observations have been made on representative test-wells in Suffolk county to learn the fluctuation in the surface of the ground-water. A ground-water map is in preparation that will show the surface of the water-table on July 1 of this year.

PIPE CROSSING AT THE NARROWS

"Three lines across the Narrows from Bay Ridge, Brooklyn, to Staten Island, Richmond borough, for the proposed pipe crossing have been investigated. Two-inch test-wells aggregating 4,000 linear feet were driven on these lines to a maximum depth of 100 feet. Rock was probably found on the Staten Island shore at a depth of 85 feet. Elsewhere the borings showed only black silt, fine sand and clay.

"Surveys of the approaches to these lines have been made on both sides of the Narrows and the results are now nearly in shape to present.

MISCELLANEOUS STUDIES AND OFFICE WORK

"In addition to the reduction of the field notes and the plotting of our surveys on the rectangular co-ordinate system adopted, the computations of the stream gaging and the working up of the ground-water observations, much work of a general character has been accomplished. We prepared during the

first months of this year a report of the development of the proposed ground-water supply from Suffolk county and its probable cost delivered in Brooklyn borough.

"We are still making some preliminary studies in connection with this development. A study has been made of earth dams on the salt-water estuaries tributary to the south shore bays, by which to exclude the sea-water from the proposed wells and galleries. A preliminary design of type of infiltration gallery which appears suitable for the Suffolk County development is now being made, with which to compare the cost of a well development there.

"In connection with the above studies, a tide gage has been maintained on the Great South bay at Babylon for several lunations, to determine the relation between the B. W. S. datum and mean sea in the bay. The total range here is little over two feet and mean tide is about one foot above our datum plane.

"Preparations are now being made to study the salinity of the waters of the Great South bay and measure the daily ebb and flow of the tide at Fire Island inlet, for the purpose of determining the danger of salt-water infiltration to the proposed ground-water works and the probable effect on the waters of the bay of diverting the fresh upland ground-waters."

Respectfully submitted,

J. WALDO SMITH,
Chief Engineer.

BOARD OF WATER SUPPLY
CITY OF NEW YORK
ENGINEERING BUREAU
299 BROADWAY

J. Edward Simmons
Charles N. Chadwick
Charles A. Shaw
Commissioners

J. Waldo Smith
Chief Engineer

New York, October 9, 1907.

Board of Water Supply,
299 Broadway, New York City.

Gentlemen:

As reported to you in Communication No. 2033, dated October 1, 1907, outlining the work which has been done on Long Island, this work is now in an advanced stage and it seems to be important that consideration be given to this entire problem with a view to ascertaining what legislation, if any, should be proposed for this winter.

The Burr law leaves some doubt as to just what the restrictions are. It would seem to be possible that it does not apply to underground waters or to streams on which filings were not made in conformity with the law. It was found that although filings were made on the lakes and ponds, few, if any, filings were made on the streams.

I respectfully suggest that it might be well to have the Corporation Counsel, through one of his assistants or through some special counsel designated for the purpose, make a special study of this law in order to determine the prohibitions on The City under it. It is generally considered that any water legislation sought for The City of New York should be ready to be introduced at the beginning of the session. It is for this reason that I am calling it thus early to your attention, in order that preparation may be made in advance.

Respectfully submitted,

J. WALDO SMITH,
Chief Engineer

BOARD OF WATER SUPPLY
CITY OF NEW YORK
ENGINEERING BUREAU
299 BROADWAY

J. A. Bensel
Charles N. Chadwick
Charles A. Shaw
Commissioners

J. Waldo Smith
Chief Engineer

New York, May 21, 1908.

Board of Water Supply,
299 Broadway, New York City.

Gentlemen:

At a meeting of the Board on August 8, 1905, the following resolution was passed:

"Resolved, That the Chief Engineer be, and he is hereby authorized and instructed to prepare a special report upon the water situation in Brooklyn, to be submitted to the Board of Water Supply as soon as practicable."

At a conference in September, 1905, with the Chief Engineer of the Brooklyn division of New York's Department of Water Supply, Gas and Electricity, it was learned that structures were already being planned by that department for the purpose of drawing upon the waters of Nassau county to the largest practicable extent, by means of infiltration galleries and additional wells, and through which it appeared probable that a repetition of the disastrous conditions of the preceding summer could be avoided for several years to come. These facts were then reported to the Commissioners.

In the report of the Board of Water Supply, made on October 9, 1905, to the Board of Estimate and Apportionment, special attention was directed to the needs of Brooklyn borough, and it was said:

"It must be recognized that the present needs of Brooklyn are even more pressing than the needs of Manhattan, and they have therefore already engaged the attention of your engineers. The water shortage in Brooklyn during the past season is almost without precedent in the history of a large American city. The consumption so outran the supply that there were hours in the day and even days at a time when houses on

upper levels are said to have been deprived of a public water-supply.

" In the course of this shortage resort was of necessity had to the throttling of gate-valves in street distributing pipes to lessen the pressure and choke the draft, so that in many parts of the City water could not be drawn in the upper stories of dwellings during the working hours of the day. This throttling of water-gates invites a conflagration hazard which is not pleasant to dwell upon.

" While Brooklyn should be given connections to the new supply from the north with all possible promptness, this relief is probably eight years off, and its quickest and cheapest source of relief is in the ground-waters of Long Island, particularly those of the region farther to the east than yet drawn upon for the City's supply.

" From this more easterly source a large surplus that now runs to waste into the sea could be taken for the use of Brooklyn, Queens and Richmond, without injury to the local communities, and which would for a long time remain one of the cheapest and purest sources, too valuable to be disregarded even after the water from the Catskill sources is delivered to Brooklyn and Queens."

On July 23, 1906, the Corporation Counsel rendered an opinion that the Board would be justified in making surveys in Suffolk county for an additional supply, and on September 19, Mr. Spear was appointed and the work incidental to the organization of the Long Island department was begun.

In compliance with your request of May 12, 1908, I present herewith, in the fewest words possible, a statement of progress in investigating the Long Island sources, and a summary of the conclusions reached on the best means of relieving the impending shortage of water in the Borough of Brooklyn and at the same time providing an additional supply of pure and wholesome water for meeting in part the increasing requirements of the Boroughs of Richmond and Queens.

Appended hereto are a map, plan and profile showing the works proposed in form as required by statute, for submission to the Board of Estimate and Apportionment and to the State Water Supply Commission (See Sheet 4, Acc. 5602) This report refers chiefly to Brooklyn as the objective point for this supply, because that borough presents the most serious problem for the solution of which the Long Island sources are neces-

sary. Although Queens can be temporarily supplied from local sources by new wells, it can be better supplied as a part of the comprehensive project herein outlined and any permanent future supply for Richmond must come through Brooklyn.

The responsibilities of the immediate future being provided for by the Department of Water Supply, there has been time for the engineers of your Board to carefully extend the studies of the ground-water conditions existing in the deep saturated sand of Long Island, begun under the Burr-Hering-Freeman Commission on Additional Water Supply, and set forth in its report of November 30, 1903, pages 619 to 886. . The Long Island department was therefore organized in your Engineering bureau, and for 18 months past, a corps of engineers, assistants, and well borers, has been actively engaged in surveys of the water sources and in a study of the special problems of determining the quantity needed for the reasonable supply of Brooklyn, the safe yield of the Nassau County sources, and the quantity and quality of the subterranean water available in Suffolk county and the best means and the probable cost of obtaining a water-supply from these new sources and transporting it to Brooklyn borough. Special studies have also been made to meet any possible objections in Suffolk county to the acquirement of these sources of supply.

These studies indicate that as much as 250 million gallons per day could be collected from Suffolk county in a year of minimum rainfall without directly tapping any of the surface streams or ponds and without serious injury to the interests of the Suffolk County towns. These communities would have a prior right to all water sufficient for their needs, however rapidly their population might increase, and this water could be furnished them from the proposed aqueducts should the diversion of the subterranean waters interfere with their present sources of supply.

The cost of this supply from Suffolk county delivered into the distribution reservoirs of Brooklyn borough would be about the same per million gallons as the water from the Catskill sources, and studies have been made on a comprehensive plan to eventually acquire a large supply from Suffolk county. For the present, however, it is proposed to build collecting works sufficient only to supply from 50 to 70 million gallons per day. These works would extend only 10 to 15 miles easterly from the Suffolk-Nassau County line.

The first supply from Suffolk county could, doubtless, be delivered to the City *within four years* from the time of actually beginning work and a portion might even be transported through the conduits of the present Ridgewood system in Nassau county *within two years,* while, on the other hand, it now appears that with good fortune attending the progress of all parts of the 100 miles of aqueduct with its deep siphons and tunnels between the Catskills and the Brooklyn reservoirs, water from the Catskill sources cannot be delivered by tunnel under the East river to Brooklyn *in less than* 8 *years* from the present time, and by that time *a large part of the supply from the northern sources will be needed to meet the growing consumption in the Boroughs of Manhattan and The Bronx.*

THE NEED FOR IMMEDIATELY BEGINNING WORK FOR OBTAINING A SUPPLY OF SUBTERRANEAN WATER FROM SUFFOLK COUNTY

The entrance of sea-water to some of the ground-water collecting works in Queens and Nassau counties has shown that the sources now supplying the Borough of Brooklyn are already overdrawn if a measure of their safe yield is their maximum delivery during years of low rainfall. Only the ample rainfall of the past two years has prevented a recurrence of the incipient water famine which prevailed in the latter part of 1905.

All water that could be secured for Brooklyn borough by additional works outside of Suffolk county would not provide a safe supply through the period which of necessity must elapse prior to the completion of the Catskill aqueduct to Brooklyn. In spite of the restraining influence of inadequate pressure in the street mains and the efforts of officials to prevent waste, the consumption of water in Brooklyn has increased in each year about eight million gallons per day over that of the preceding year. Doubtless the consumption will increase at a still more rapid rate during the next 10 or 20 years with the increase of population resulting from the completion of new bridges and tunnels to Manhattan and with a more liberal supply of water than has been furnished in the past.

In the year 1907, the actual consumption of Brooklyn borough was 145 million gallons daily including the water supplied by private water companies. A conservative estimate of the

rate of increase indicates that in 1916, the earliest date for delivery of Catskill water into Brooklyn, the consumption will exceed 225 million gallons daily, in addition to the increased demands of Queens borough which might not be supplied from local sources and in addition to a supply for Richmond borough.

The greatest possible development of the sources in Nassau and Queens counties available for the supply of Brooklyn borough would not yield more than 170 million gallons per day in such years of low rainfall as occurred on Long Island from 1879 to 1883, and the yield would be still smaller if the rainfall should be as deficient as during the years from 1831 to 1849. During years of normal rainfall and with the largest reasonable development, the complete works could not provide a supply of more than 195 million gallons per day, but this cannot be considered the safe supply from these works. There is even a probability that some of the present sources will have to be abandoned in the future because of infiltration of sea-water and the encroachment of population over the gathering ground.

Early relief can only be secured from Suffolk county. If an ample supply be secured from these sources, the aqueduct and tunnel from Hill View reservoir across the East river to Brooklyn, proposed in the report of October 9, 1905, and estimated to cost $4,344,000, can be deferred.

THE SOURCE OF SUPPLY FOR THE PROPOSED WORKS

As already stated, it is proposed to divert only the subterranean waters from Suffolk county and not to draw directly from any of the existing ponds or streams. The test-borings have proved that strata of porous sand and gravel, saturated with water, extend substantially the entire length of Long Island, reaching from the so-called "backbone" of the island southward to the sea. The source of this water is the rainfall. The character of the surface causes this to be absorbed more rapidly and in greater proportion than upon most watersheds in this part of the country, and it slowly percolates seaward, flowing underground at a rate seldom greater than one mile per year, so that by the time it reaches the proposed line of diversion it has received the most perfect filtration and purification from surface pollution.

About 30 per cent. of the volume of sand or gravel is pore space, and the lowering of the plane of saturation in this deep

gravel over many square miles of area gives a storage reservoir of enormous volume within which the varying rainfall and absorption at different seasons is equalized and from which The City could draw, but from which one may not prudently take more than the average rainfall supplies.

In addition to the underflow, there is at times, following heavy rainfalls, a considerable flow in various rivers and streams which now escapes to the sea unused, but which can in part be restrained in its course by impounding dams and thus caused to soak into the porous ground and be thus added to the natural ground-water. A few such reservoirs are provided for in the proposed works.

TYPE OF DIVERSION WORKS PROPOSED

It is proposed to divert this underground water in Suffolk county on a line nearly parallel to the south shore of the island, somewhat back from the populous villages and the salt waters of the south shore bays in country now but sparsely settled and covered to a large extent with low growths of scrub oak and pine. On this line a right-of-way 600 to 1,000 feet in width would be acquired for the proposed works by which the supply would be collected and transported to New York City.

According to the present plan, the ground-waters would be gathered by means of wells about 100 feet to 200 feet in depth, spaced 500 to 1,000 feet along the center of this right-of-way. By means of suitable pumps operated from one or more central power-stations, the water collected in the wells would be delivered into the aqueduct through which it would be conveyed to the City.

It is proposed to transport the entire Suffolk County supply to Brooklyn borough in a continuous gravity aqueduct of masonry having a nominal capacity not exceeding 250 million gallons per day. At the westerly end of this aqueduct in Brooklyn borough a pumping-station is proposed to lift the water to a covered distribution reservoir at the elevation necessary to give it the desired pressure in the distribution pipes.

EXTENT OF WORKS PROPOSED

As already stated, the intake works proposed for construction in the near future comprise only the works appurtenant

to from 10 to 15 miles of aqueduct extending easterly from the Suffolk-Nassau County line approximately parallel with the south shore.

Studies of the yield of certain wells in Nassau county that have been operated many years for the supply of Brooklyn, demonstrate that a yield of 70 million gallons daily may be expected from the proposed collecting work on this first 15 miles of line. This quantity is deemed sufficient for the immediate need of additional supply in the Borough of Brooklyn, but it is proposed to build the aqueduct all the way to the proposed pumping-station near Ridgewood of a capacity such that it could convey a volume of water of about 250 million gallons daily and thus be available for the extension of these works eastward from time to time to any required extent along the location shown on the accompanying map (Sheet 4, Acc. 5602). And application should now be made to the State Water Supply Commission for the appropriation of the waters for the entire length shown for the purposes herein described.

The ground is exceptionally favorable for the cheap construction of a large aqueduct of concrete of the so-called "cut-and-cover" type, and after studies of aqueducts of various dimensions, it is found that the additional cost of building the aqueduct of the full size is much less than it would cost to build a 100-million or 150-million-gallon aqueduct at present and supplement it 10 or 20 years later by a second parallel aqueduct.

By having this aqueduct of the size proposed, it would greatly simplify the work of extension, corresponding to growth in population and, moreover, it would serve to safeguard The City against the possible breaking of the present aqueduct, a part of which is now very old, and under present conditions cannot be shut off for a single day for inspection or repairs. The water from the present driven wells and infiltration galleries of Nassau county could, in case of accident, be very quickly turned into the proposed new aqueduct through suitable connections, pending repairs or reconstruction of the old conduits.

FUTURE BRANCH LINES TO INTERIOR VALLEYS

In order that the works now to be built may form part of a comprehensive system and be well adapted for future exten-

sion a comprehensive study has been made of all the subterranean water resources of Suffolk county.

With a view to developing these resources to the fullest reasonable extent in the somewhat distant future, and in order to safeguard the supply in the case of the recurrence of years of exceptionally low rainfall, such as are of record in the past, without being compelled to pump the wells along the aqueduct line to an extent that would cause serious disturbance to local interests, or that would endanger the drawing in of salt or brackish water to the porous sands from which the supply is to be drawn, provision has been made for certain branch lines, shown on the accompanying map (see Sheet 4, Acc. 5602), and extending up along several of the valleys to the interior of the island, from which a large quantity could be diverted by deep pumping and in effect utilizing the interstices in these vast masses of saturated gravel as storage reservoirs to be drawn on during the period of low rainfall and left to fill again during the years of abundant rainfall.

ESTIMATED COST OF WORKS

For the first installment; consisting of about 15 miles in length of collecting aqueduct and wells in the western end of Suffolk county, including costs of land, damages, legal expenses, construction costs for wells, power-plant and accessories. Construction of the conveying aqueduct of mean capacity not exceeding 250 million gallons daily from Suffolk county to Brooklyn borough, also the construction of the pumping-station there.

Estimated yield	70 million gallons daily
Estimated cost complete	$21,742,000

A portion of this supply, perhaps 50 million gallons per day, might be delivered to the City through the proposed 72-inch pipe-line and the pumping-stations proposed in Nassau county by the Department of Water Supply. This amount of water could be obtained by the construction of about 10 miles of the collecting aqueduct and wells proposed above and by the extension of the main aqueduct about 2 miles into Nassau county to connect temporarily with the Brooklyn works. The estimated cost would be $7,153,000, exclusive of the expendi-

ture for the 72-inch pipe and pumping-stations by the Department of Water Supply.

The estimated rate of expenditure year by year would be approximately as follows:

Preliminary, land, etc.	$1,000,000	Substantial completion of preliminary stage for 50 million gallons daily
1st year of actual construction	2,500,000	
2nd year of actual construction	3,700,000	
Total preliminary stage	**$7,200,000**	
3rd year of actual work	$3,500,000	Completion for development of 70 million gallons daily
4th year of actual work	6,000,000	
5th year of actual work	5,000,000	
Additional first stage	**$14,500,000**	
Total completion of first stage	**$21,700,000**	

Following this first stage, the collecting aqueduct could be extended eastward gradually to meet the growing demand and corresponding additions made to pumps and power-plants at 3-year or 5-year intervals as needed.

Outline plans, surveys and estimates of cost have been made for the entire project shown in the plans and profiles submitted herewith. These show that for this complete development of Suffolk County sources to be attained perhaps 30 years hence, and capable of delivering a volume of water not exceeding 250 million gallons daily exclusive of the branches to the interior valleys the total cost would be $40,-479,000, making this water cost delivered in Brooklyn borough $39 per million gallons.

Adding the branch lines in order to avoid lowering the water-table so severely near the aqueduct line in case of a series of years of very low rainfall, the total cost would be increased to $47,173,000, making the water cost delivered in Brooklyn borough $44 per million gallons.

In considering the expenditure for collecting works in Suffolk county on a comprehensive scale, it should be remembered that the cost per million gallons is ultimately about the same as for the Catskill water and that its use will serve to postpone the date for the Catskill extensions, and that by a connection between the main arteries of Manhattan and Brooklyn the two boroughs would be better safeguarded than if all the additional water must come from the north.

Respectfully submitted,

J. WALDO SMITH,
Chief Engineer.

We have given careful study to the subject matter of the above report and concur fully in the statements and conclusions presented therein.

JOHN R. FREEMAN,
Consulting Engineer.
WM. H. BURR,
Consulting Engineer.

Acc 5602

M. B. BROWN PRINTING & BINDING CO., N. Y.

BOARD OF WATER SUPPLY
CITY OF NEW YORK
299 BROADWAY

Commissioners
J. A. Bensel
Charles N. Chadwick
Charles A. Shaw
Thomas Hassett, Secretary

New York, June 8, 1908.

Hon. George B. McClellan, Mayor,
Chairman of the Board of Estimate and Apportionment,
City Hall, New York.

Sir:

Under date of October 9, 1905, we sent you in accordance with Chapters 723 and 724 of the Laws of 1905, a report upon certain sources of additional water-supply for The City of New York, the development of which was therein estimated to cost $161,857,000. These sources were the Esopus, Schoharie, Rondout, Catskill and certain minor watersheds in the Catskill mountains. This report was accompanied by a map, plan and profile of the proposed works, and said report and map were duly approved by your Board October 27, 1905, and with the exception of the Schoharie watershed and except also in certain minor respects, by the State Water Supply Commission May 12, 1906. Work is now proceeding pursuant to the authority thus granted.

Since August 8, 1905, this Board has been investigating carefully the situation of water-supply on Long Island and the necessary development of this supply for the purposes of supplying the Boroughs of Brooklyn and Richmond. We herewith present the plan for submission to the State Water Supply Commission for approval, which plan is for the development of the underground water sources of Suffolk county, these being additional sources not included in the general plan of October 9, 1905, or in the estimate of the money required to carry out the same.

In carrying out this plan the studies made by this Board show the following:

Time of delivery of first water to conduits of Ridgewood system at Suffolk County line....	2 years
Cost of said two years' work..................	$7,200,000
Time of delivery of first water to Brooklyn without use of conduits of Ridgewood system....	4 years
Cost of said four years' work..................	$16,700,000
Time of development of first installment of 70,000,000 gallons daily....................	5 years
Cost of said five years' work, including full size concrete cut-and-cover aqueduct to Brooklyn and pumping-station in Brooklyn...........	$21,700,000

The country is exceptionally favorable for the cheap construction of this type of aqueduct, and the best economy dictates that the aqueduct shall be constructed of full size rather than to be constructed in the first instance of smaller size and later supplemented by another aqueduct.

Outline plans, surveys and estimates of cost have been made for the entire project shown on the plan and profile submitted herewith. These show that for the complete development of the Suffolk County underground sources, yielding about 250,000,000 gallons per day, the cost will be $47,173,000.

In considering the expenditures for collecting works on a comprehensive scale, it should be remembered that the cost per million gallons is ultimately about the same as for the Catskill water and that its use will serve to postpone the date of the Catskill extensions, and that by a connection between the main arteries of Manhattan and Brooklyn, the two boroughs will be better safeguarded than if all the additional water must come from the north.

The land to be taken is sparsely settled and covered with low growths of scrub oak and pine, and will consist of a right-of-way from 600 to 1,000 feet in width along which will be driven the necessary wells. These wells will be operated from one or more central power-stations and will deliver their water into the aqueduct which will conduct the supply to the Brooklyn pumping-station.

Since our investigations on Long Island commenced, the necessity for the development of Suffolk county has become acute on account of the increasing shortage of water in

Brooklyn and Queens and on Staten Island. The entrance of sea-water to some of the ground-water collecting works in Queens and Nassau counties has shown that the sources now supplying the Borough of Brooklyn are already overdrawn if a measure of their safe yield is their maximum delivery during years of low rainfall.

If your Board and the State Water Supply Commission approve the plan herewith presented, it is our purpose to take and divert only the subterranean sources in Suffolk county with due regard for the rights and interests of the inhabitants of said county and not to divert into the City aqueduct water from any surface streams or natural ponds.

We forward to you herewith a general map, plan and profile of the proposed works (Sheet 4, Acc. 5602), and respectfully request that in accordance with Section 3 of Chapter 724 of the Laws of 1905, as amended by Section 1 of Chapter 314 of the Laws of 1906, your Board will appoint a day for a public hearing and give at least eight days' public notice thereof as directed by said statute.

We respectfully request that when and if said map shall be approved by your Board, the same be signed and certified and forwarded to the State Water Supply Commission as soon as practicable, and that the Corporation Counsel be requested by your Board to prepare the necessary petition and other papers and to take the other steps necessary for submission of this application to said Commission.

Respectfully,

J. A. BENSEL,
CHARLES N. CHADWICK,
CHARLES A. SHAW,
Commissioners,
Board of Water Supply.

BOARD OF WATER SUPPLY
CITY OF NEW YORK
ENGINEERING BUREAU
299 BROADWAY

J. A. Bensel
Charles N. Chadwick
Charles A. Shaw
Commissioners
J. Waldo Smith
Chief Engineer

New York, June 12, 1908.

Board of Water Supply,
299 Broadway, New York City.

Gentlemen:

At a meeting of the Board on August 8, 1905, the following resolution was passed:

"Resolved, That the Chief Engineer be and he is hereby authorized and instructed to prepare a special report upon the water situation in Brooklyn, to be submitted to the Board of Water Supply as soon as practicable."

As legislative restrictions prevented the taking of water from Suffolk county, it was considered that the above resolution applied particularly to Nassau county. By conferring with the Chief Engineer of the Department of Water Supply, Gas and Electricity for the Borough of Brooklyn, it was learned that plans were already under way in that department for the development of the sources of Nassau county to the largest extent practicable. For this reason it seemed unwise and unnecessary for this Board to formulate any plans for obtaining water from that county and it was so reported.

The legislative restriction on Suffolk county was set forth in the hearings before the State Water Supply Commission on the Catskill plan, including the statement that supplies from both the Catskills and Suffolk county would be advisable, if The City were free to take the latter.

It was also stated in the report of October 9, 1905, that Brooklyn must look for immediate relief to the water in the deep sands of Long Island.

From the investigations and report of the Burr-Hering-Freeman Commission, it appears plain that if the present rate

of increase in consumption continues, Brooklyn cannot be properly asked to wait for the new supply from the north.

From the studies of the ground-water supply presented in the report of John R. Freeman, Civil Engineer, to Bird S. Coler, Comptroller, in the year 1900, and particularly from the more elaborate investigation of the Long Island underground sources made by the Burr-Hering-Freeman Commission, it is plain that the additional sources most quickly available for relieving the great need of Brooklyn for more water, are to be found on Long Island, and no effort should be spared to make all those sources available. Nevertheless, Brooklyn must also be in part supplied from the Catskill sources, and, as already mentioned, a branch aqueduct for this purpose is shown on the accompanying map (Sheet 4, Acc. 5602).

Your Engineering Department has already begun studies directed toward the further exploration of the deep underground sources of Long Island, and, purely as a matter of obvious and prompt relief as well as of good engineering, regardless of present legislative limitations, feels it incumbent as a matter of engineering to record the fact that while Brooklyn should be given connections to the new supply from the north with all possible promptness, this relief is probably eight years off, and that its quickest and cheapest source of relief is in the ground-waters of Long Island—particularly those of the region farther to the east than that yet drawn upon for the City supply. From these more easterly sources a large surplus that now runs to waste into the sea could be taken for the use of Brooklyn, Queens and Richmond without real injury to the local communities, and it would for a long future remain one of the cheapest and purest sources, too valuable to be disregarded, even after water from the Catskill sources is delivered to Brooklyn and Queens.

Fortunately the structures required for securing this ground-water and delivering it into Brooklyn are of a simple character, permitting very rapid construction and therefore early relief, providing existing complications can be met and overcome.

The responsibility for the temporary relief of Brooklyn being immediately provided for by the Department of Water Supply, Gas and Electricity, there was time for the engineers of your Board to carefully consider the problem of obtaining a permanent supply from the region east of Nassau county.

During the latter months of 1905 and the early part of 1906 this was kept constantly in mind, and studies progressed in this office so that on May 23, 1906, a report was made to the Board recommending that extensive surveys and investigations be made in order to determine the best plan for developing the water sources of Suffolk county and so as to be able to show just what The City proposed to do. This report also suggested that the Corporation Counsel be requested to give an opinion as to whether the Board, in view of the restrictive legislation affecting Suffolk county, had the right to carry on the preliminary work necessary for the preparation of a plan for taking the water from that county. This request was made, and on July 23, 1906, an opinion was rendered stating that the Board was justified in making surveys and investigations in restricted localities and spending the funds appropriated for the Board on such investigations, so far as might be deemed necessary.

Steps were immediately taken toward the organization of the Long Island department and outlining plans for a complete investigation of the Suffolk county sources. On September 19, 1906, Mr. Walter E. Spear was appointed division engineer and on October 19 he reported for duty, being placed in charge of the work on Long Island, with instructions to make the surveys and investigations necessary for the preparation of a plan which contemplated the eventual development of all the readily available supply of water in southern Suffolk county.

On March 15, 1907, and October 21, 1907, I made special reports regarding the progress of these investigations to those dates.

On December 4, 1907, I gave you a very complete outline of the entire work, together with the special studies then nearing completion.

On May 21, 1908, I submitted a report and plan describing the source of and manner of obtaining a supply of water from Suffolk county.

The preliminary work now being completed, I beg to submit the detailed report of the investigations, surveys, studies and plans, made under my direction, looking to the development of a water-supply from Suffolk county and conveying it to the Borough of Brooklyn.

The present investigations, supplementing those carried on

by the Burr-Hering-Freeman Commission in the year 1903, have been very thorough and comprise among others inquiries into the amount of ground-water available and the best method of developing it; the effect on vegetation of a possible lowering of ground-water level; the effect of the reduction of the ground-water flow on the oyster industry; a thorough study of the maximum yield from both Nassau and Suffolk counties; the general design of the necessary works for developing this supply, including pumping-stations and other equipment, and an estimate of the cost of the entire project, made in detail for the successive stages of the development.

The work of the Long Island department was begun on October 19, 1906, and immediately following this date, a corps of engineers was collected and organized into three sections. The office of the department was established at Babylon, Long Island, and field offices were secured at Patchogue and Eastport.

As a basis for the topographical surveys a triangulation system was established and careful lines of levels run over the entire area to be covered by the examinations.

In order to supplement the rainfall stations maintained by United States Weather Bureau three other gages were established, one each at Babylon, Lake Ronkonkoma and Center Moriches.

The flow of twenty of the larger streams in Suffolk county has been continuously measured and careful observations have been made on some of the smaller ones. On eight of these larger streams the gaging has been done by means of weirs especially constructed for this purpose.

In order to determine the ground-water levels 504 test-wells, 2 inches in diameter, averaging from 30 to 100 feet in depth, were driven in the territory between Amityville and Quogue, and Port Jefferson and Riverhead. In addition to these wells, observations were made on the water of practically all ponds, lakes and existing wells within Suffolk county. In connection with this work about 2,600 samples of the sands and gravels penetrated by these wells have been preserved and in order to determine the period and amount of fluctuation of the ground-water surface, monthly measurements of its hight have been made on representative test-wells.

For the purpose of determining the best means of securing the deep ground-waters as well as to aid in the design of the

well stations, it was deemed advisable to drive a number of large deep wells and pump from them for a sufficient length of time to establish, for this purpose, the extent to which the ground-water may be locally developed. An outfit for driving California stovepipe wells from 12 to 16 inches in diameter was obtained and 8 test-wells have been put down. Three of these wells, in West Islip, were fitted up with air-lift systems and the pumping experiments carried out on them. The other five wells served the purpose of delimiting the extent and showing the character of the deep sands and gravels. Many other collateral studies bearing on the question of obtaining these waters together with estimates of cost and design of structures were also made.

YIELD OF QUEENS AND NASSAU COUNTY SUPPLIES

The Borough of Brooklyn is now supplied with water from the works of the Ridgewood system in Queens and Nassau counties and from several small municipal and private waterworks located within the borough limits.

The Ridgewood system, which furnishes about 85 per cent. of the entire present supply, has a catchment area, which could easily be developed, of 159 square miles. The calculation of the yield of this system for the years 1905, 1906 and 1907 (below, equal, and 12 per cent. above the average rainfall respectively) shows that the total safe present yield may be estimated at 117 million gallons daily. A complete development of the entire 159 square miles would give a total safe yield, during years of normal rainfall, of 155 million gallons daily, but in a period of dry years the safe yield would not be in excess of 138 million gallons daily.

The sources now supplying Brooklyn, other than the Ridgewood system are estimated to have a safe yield during years of average rainfall of 32 million gallons daily, and a complete development within the limits of the borough would yield a total of 40 million gallons daily during the years of average rainfall, but not more than 30 million gallons daily during a period of dry years.

It is evident, therefore, that the present area developed to its fullest capacity cannot be depended upon to yield continuously more than 170 million gallons daily. These capacities are clearly shown in the following table:

YIELD IN MILLION GALLONS DAILY

	Catchment Area Square Miles	In a Year of Deficient Rainfall	In a Year of Average Rainfall
Ridgewood System	159	...	...
Present	..	105	117
Under construction	...	8	10
Possible	...	25	28
Total	...	**138**	**155**
All other works within Borough limits.	...	...	...
Present	...	15	18
Under construction	..	12	15
Possible	...	5	7
Total		**32**	**40**
Grand total	...	***170**	**195**

*The low rainfall yield in this table represents the probable delivery of the works during the next few years should they be dry ones. The high rainfall of the past few years has filled the ground-water reservoirs and this storage will be drawn upon for several years to come. Should the rainfall continue below the normal for say five consecutive years, the total yield from these sources might not be over 150 million gallons daily

THE CONSUMPTION OF WATER IN THE BOROUGH OF BROOKLYN

The population of Brooklyn is estimated at 1,470,000, and the average supply from all sources in 1907 was 145 million gallons daily. The per capita consumption of 98.6 gallons per day during that year was low, due to the fact that the supply had been insufficient for some years and to the reduced pressures which were maintained in the distribution system. Since 1902 the consumption has been greater than the supply which the present works would have yielded had the rainfall during the intervening years been normal; but, inasmuch as during this period the rainfall was about 3 inches in excess of the normal no particular trouble was had. In the case of a full development of all the supplies in western Long Island and in the event of a period of low rainfall, the total available supply will hardly be sufficient for the needs of Brooklyn through the year 1910.

URGENCY OF THE NEED FOR RELIEF OF BROOKLYN BOROUGH

It is evident, therefore, that an additional supply of water from sources outside of western Long Island should be made available at the earliest possible time as some water from them may be needed by the year 1910. No relief can be obtained from the Catskill sources for it will be impossible to complete

these works to the extent necessary to deliver water to Brooklyn, at the earliest, before 1916. The only source which can, within a reasonable time, be made available after the full development of the present supplies lies in the ground-waters of Suffolk county and steps should at once be taken to develop them.

The works necessary to collect and transport these waters to the City cannot, however, be completed for several years, and, in the meantime, the present available sources in western Long Island should immediately be developed to their full capacity in order to prevent the possibility of the occurrence of a serious shortage before relief can be obtained from the Suffolk County sources.

SUPPLY FROM SUFFOLK COUNTY GROUND-WATER SOURCES

The ground-water from the south side of Long Island would be pure and wholesome, except for the small amounts of mineral salts usually found in such waters. It would be free from any pollution or infection. It would be clear and colorless and its appearance, taste and temperature would be pleasing.

It is proposed to make available for the use of New York City all of the deep ground-waters that are not needed for local use in southern Suffolk county from the Nassau county line to Shinnecock bay, and to include also the surplus ground-waters of the coarse sands and gravels in the Peconic valley.

Area of and Rainfall on Suffolk County Watershed

The total watershed area proposed to be so made available is 332 square miles, of which 38 square miles are included in the Peconic area. The average annual rainfall on this area is estimated to be 46 inches, and estimating that 37 per cent of this can reasonably be made available, a total of 265 million gallons daily could be obtained, provided that an adequate amount of ground-water storage is available. During extremely dry periods ample storage can be obtained from the interior of the island by means of branch aqueducts and wells to be used only during such dry periods as cause unusual depletion of the ground-waters along the south shore.

Population on Suffolk County Watershed

The resident population on this watershed is 39,000, of which number only 17,000 are within the area which would be affected by the operation of the works. It is not probable that 50 years hence the population will exceed 150,000, and if this number were to be provided with water they would probably require not more than 15 or 20 million gallons daily, and this amount, in making an estimate, should be reserved for the uses of the resident population. It is safe, therefore, to say that for many years New York City can secure 250 million gallons daily from these Suffolk county sources.

METHOD OF COLLECTING THE GROUND-WATER

A line of deep wells at intervals along the center of a right-of-way 600 to 1,000 feet in width would be put down. Such a width of right-of-way would be necessary to prevent encroachment of buildings and the consequent danger of pollution. This right-of-way would be located in a sparsely settled and but little cultivated country, consisting as it does, largely of scrub oak and pine barrens. This location would be north of the large villages and some distance from the ponds on the south shore, and also sufficiently distant from the sea to cut down to a minimum the possibility of the infiltration of salt. The water would be pumped into the collecting aqueduct by means of deep well pumps and electric motors, each motor being operated independently from substations located at intervals of about 4 miles, the central power-station being located on Great South bay near Patchogue.

Reservoirs to Prevent Ingress of Salt

In order to be positively sure that no salt would be drawn in from the ocean 12 dams would be built on the estuaries of the 12 larger south shore streams for the purpose of creating reservoirs of fresh water, which would tend to hold back and prevent the ingress of the salt.

Provisions to Maintain Supply During Very Dry Periods

In order to offset the continuous drain upon the ground-water which would be necessary during the periods of low rainfall, three branch aqueduct lines would be run to secure

the water stored in the deep strata in the center of the island. Deep wells would be driven along these lines, but pumping from them would only be done during periods of extreme drought.

Development of the Peconic Valley Waters

The ground-waters in the Peconic valley would be developed by means of a line of wells along the south bank of the river from Riverhead to Calverton, and a pumping-station at Riverhead would deliver the water over the divide into a gravity aqueduct which would connect with the main aqueduct near Quogue.

Conservation of Surface Flood Flows

The flood flows of four of the larger streams would be caught in small storage reservoirs above the main line of the collecting works and wells driven around their margins so that the water contained in these basins would be drawn down through their sandy bottoms and thus purified. These wells would be in operation only when the flow of the streams is in excess of their normal discharge.

PROTECTION OF SUFFOLK COUNTY INTERESTS

Present use of Water

The amount of water now being used for the purpose of the resident and transient population is relatively small, being about 6 million gallons daily for domestic and commercial uses, and about 80 million gallons daily for water-power. The waters of most of the surface streams are now running unused into the sea. The water necessary for domestic and commercial uses, would, in case of the development of these sources, be supplied by New York City at a reasonable price should the proposed works interfere with the present supply, and assurance should be given to all of the towns and villages that New York will always provide for them in the future as their population increases.

Maintenance of Surface Streams and Ponds

Surface streams and ponds would possibly be slightly lowered by the draft on the ground-waters but in this event the

water-power could probably be replaced by steam or electric plants at small expense, and the ponds maintained at their present spillway elevation by delivering to them sufficient water to accomplish this purpose, just as Brooklyn is now doing in the case of the lower Massapequa pond. Little of the water so used would be lost because most of it would be drawn back to the collecting works through the bottoms of the ponds, thus establishing a beneficial circulation. The cost of thus caring for these ponds would be that of pumping the amount of water necessary to keep them full, but this would be, to some extent at least, offset by the beneficial influence which they would exert toward protecting the collecting works against the entrance of sea-water.

Effect on Agricultural Interests

The elevation of the water in the wells of the few farms located north of the south shore villages would be lowered somewhat but the total resulting damages to crops would be very small.

Investigations have shown when the ground-water level is over 5 feet below the surface of the coarse Suffolk County soil that no moisture reaches either the surface or the roots of vegetation through capillary action. Ninety-three per cent. of the entire catchment area now receives all of its moisture from above, none of it coming from the ground-water.

The Suffolk County catchment area proposed to be developed is 212,000 acres. Of this total area, that within which the surface of the soil is less than five feet above the ground-water and within a mile of the main collecting works aggregates only 10,100 acres or 4.8 per cent. of the whole. Included in this 10,100 acres are 4,000 acres of water surface and swamp area which latter would be benefited by any lowering of the ground-water level. Of the remaining 6,100 acres it is estimated that only 850 acres or only 0.4 per cent. of the entire watershed area are under cultivation.

Effect on the Oyster Industry

The oyster industry of the Great South bay is one of considerable importance, and in order to show that the diversion of the ground-waters would not cause great damage to it, a careful study of the question was made. The results obtained indicate that about 85 per cent. of the present oyster-beds

would, after the diversion of the ground-waters has been accomplished, still be within the limit of salinity favorable for oyster culture; that about 6 per cent. might be slightly injured but that over 9 per cent. of the area of the bed suitable for this purpose would actually be improved. The net result of the diversion would, therefore, be a substantial improvement of the conditions necessary for successful oyster culture, in both Great South bay and Shinnecock bay.

Resulting Direct Advantages

Among the direct advantages to be gained by Suffolk County residents may be mentioned the building of new highways parallel to the south shore, and the resulting increased accessibility of the large areas of the island; much money will be expended in the county for property, for labor and for material; the quality of the water supplied to the villages from the proposed works will be materially better than that which they now have and many improvements will be made by The City on its right-of-way and in connection with its works. Here, also, should be mentioned both the improvement in the appearance and navigation of the estuaries, the mouths of which are to be closed by dams, for the purpose of forming fresh-water ponds.

VALUE OF THE DAMAGES DUE TO LOWERING THE GROUND-WATER

The damages resulting from the lowering of the ground-water level would be smaller, the wider the right-of-way taken, since the depression of the water-table outside a wide right-of-way would be comparatively small.

On account of the operation of the present well systems in Queens and Nassau counties, many actions for damages have been brought against The City. The amount of the award in particular cases has been influenced by the location of the property with reference to the pumping-station, by the relative elevation of the water-table, by the data available to The City for the defense by the way in which the case was presented and by the judge before whom it was tried. From 1902 to 1906 most of the cases were settled without formal trial, and the awards made during the period were greater than those in previous years.

So far as possible all suits against The City and their disposition have been brought together and compiled. This study shows that 133 suits have been brought; that 30 of them are still pending; that the total amount claimed was $1,508,061 and that the awards in 103 cases aggregated $201,486 on a total amount claimed of $1,285,279.

TRANSPORTATION OF THE SUPPLY TO NEW YORK CITY

The plan contemplates the construction of a concrete cut-and-cover aqueduct having a capacity of 250 million gallons daily from Great River to Brooklyn borough at a point near the present Ridgewood pumping-station. East of Great River the aqueduct would diminish in size approximately in proportion to the drainage area above it until at a point near Quogue its capacity would be 50 million gallons daily. This aqueduct would convey the entire supply by gravity and for nearly its entire length would be on the hydraulic gradient, there being only three comparatively small siphons.

The capacity of the Peconic aqueduct would be 50 million gallons daily, and that of the three branch aqueducts to the center of the island would also be 50 million gallons daily each. Aside from the lift over the Peconic divide, the entire supply after being delivered from the wells into the aqueduct would flow freely to the Borough of Brooklyn, there to be either pumped into a reservoir or directly into the distributing mains.

ORDER OF CONSTRUCTION AND COST OF SUFFOLK COUNTY WORKS

The first step in this development should be one looking toward the delivery of 50 million gallons daily by the year 1910, if possible. This could be done at a cost of about $7,153,000 or about $37.80 per million gallons, by slightly increasing the slope of the hydraulic gradient of the 72-inch steel pipe which the Department of Water Supply plans to extend from Clear stream to Massapequa, and by constructing the first ten miles of the Suffolk County collecting works and building the necessary conduits to conduct this supply to the pumping-stations, which the Department of Water Supply proposes to build at Massapequa and Wantagh.

The next step in the development of this supply would in-

clude the construction of the main aqueduct, full size, from Ridgewood in Brooklyn to Great River, together with the further development of these 15 miles in Suffolk county. This can be done at a cost of about $21,742,000 and would result in a supply of 70 million gallons daily at a cost of about $62.20 per million gallons.

The next stage would include the development of the 15 miles between Great River and South Haven from which, together with the works already completed, a yield of 150 million gallons daily could be obtained, at a cost of about $30,262,000 or about $44.50 per million gallons, while for an estimated cost of about $38,355,000, 220 million gallons daily at a cost of about $40.10 per million gallons, can be obtained by developing the remainder of the south shore, 19 miles in length, to a point near Quogue. The collecting works necessary for developing the Peconic valley would raise the cost of the development to about $40,479,000 and the total supply to 250 million gallons daily during average years at a cost of about $39.20 per million gallons. To this latter figure, however, must be added the cost of the three branch aqueducts to the center of the island, which are necessary, in order to maintain the supply of 250 million gallons daily during a period of dry years. The total cost of the entire development is therefore estimated at about $47,173,000, or at a cost of about $44.20 per million gallons, delivered into the distribution system of Brooklyn borough.

The results of these investigations, which are generally stated in the foregoing, are given in great detail in the report of Division Engineer Walter E. Spear and the numerous plans, tables and diagrams transmitted herewith. In order that these data may be preserved and may be quickly available for those to whom it will be useful, I respectfully request that they be properly edited and printed.

Respectfully submitted,

J. WALDO SMITH,

Chief Engineer.

BOARD OF ESTIMATE AND APPORTIONMENT CITY OF NEW YORK

Whereas, The Board of Water Supply of The City of New York, pursuant to Chapter 724, Laws of 1905, as amended, have made such surveys, maps, plans, specifications, estimates and investigations as they deemed proper in order to ascertain the facts as to what sources where an additional supply of pure and wholesome water for The City of New York exist and are most available, desirable and best for the said supply; and

Whereas, The said Board of Water Supply have reported to the Board of Estimate and Apportionment, under date of June 8, 1908, recommending the development of the underground sources of water-supply in Suffolk county, Long Island, New York, and have presented to the Board of Estimate and Apportionment, with said report, a map, plan and profile dated February 25, 1908, and entitled "Board of Water Supply of The City of New York. Map and Profile Showing Manner of Obtaining from Suffolk County an Additional Supply of Water for The City of New York"; and

Whereas, The Board of Estimate and Apportionment, upon the receipt of the said report and the said map, plan and profile, and on the 12th day of June, 1908, adopted a resolution that June 26, 1908, at 10.30 o'clock in the forenoon, at Room 16 in the City Hall, Borough of Manhattan, City of New York, be fixed as the time and place for the public hearing upon the said report, map, plan and profile, and that notice be given of such public hearing by publication in the City Record and the corporation newspapers published in Kings county, and in two newspapers published in each of the Counties of Suffolk, Nassau, Queens, Richmond, New York and Westchester, such publication to commence Tuesday, June 16, 1908, and to be continued in each issue of each of said papers to and including June 26, 1908, such notice being by said resolution declared to be reasonable public notice of such hearing; and

Whereas, The Board of Estimate and Apportionment, in order to afford to all persons interested a reasonable opportunity to be heard respecting the said report, map, plan and profile, have given reasonable public notice of such hearing, and in addition have given notice of such hearing by mailing to the Chairman and Clerk of each of the Boards of Supervisors of the Counties where real estate to be acquired is situated, a notice of such hearing at least eight days before the

26th day of June, 1908, namely, to the Chairman and Clerk of the respective Boards of Supervisors of the Counties of Suffolk, Nassau, Westchester, and to the President of the Board of Aldermen of The City of New York, and to the City Clerk of The City of New York for the Counties of New York, Kings, Queens and Richmond; and

Whereas, The said notice of said hearing was published in all of the papers specified and referred to above, being the City Record and the Brooklyn Daily Eagle, the Brooklyn Citizen, the Brooklyn Standard Union, the Brooklyn Free Press and the Brooklyn Times, being the corporation newspapers published in Kings county, and in the New York Herald and New York Times, being two newspapers published in New York county, and in the Democratic Register of Ossining, and in the Eastern State Journal, being two newspapers published in Westchester county, and in the Staten Island World and Richmond County Herald, being two newspapers published in Richmond county, and in the Long Island City Star and the Long Island Farmer, being two newspapers published in Queens county, and in the North Hempstead Record and the Republican, being two newspapers published in Nassau county, and in the Riverhead News and the County Review, being two newspapers published in Suffolk county; all of which is evidenced by the affidavits, certificates and documents filed in the office of the Secretary of the Board of Estimate and Apportionment; and

Whereas, On the 26th day of June, 1908, at 10:30 o'clock in the forenoon, in Room 16 in the City Hall, Borough of Manhattan, City of New York, the Board of Estimate and Apportionment met pursuant to said notice and a public hearing was given to all persons interested and a reasonable opportunity to be heard respecting the said report, map, plan and profile was afforded to such persons, at which hearing the said report, map, plan and profile were considered and due deliberation was had; and many having appeared in opposition to said report, map, plan and profile, and also many in favor thereof; now, therefore, be it

Resolved, That the Board of Estimate and Apportionment hereby approves and adopts the said report, dated June 8, 1908, and the said map, plan and profile, dated February 25, 1908, and hereby directs that the said map, plan and profile be executed, signed, certified and filed as directed in Section 3 of

Chapter 724 of the Laws of 1905, as amended, and hereby declares the same to be the final map, plan or plans and profile approved and adopted by the Board of Estimate and Apportionment as provided for in said section; and be it further

Resolved, That the said Board make application by petition in writing to the State Water Supply Commission as speedily as possible for the approval of the said report, map, plan and profile, pursuant to Chapter 723, Laws of 1905, as amended, and that the Corporation Counsel be and he hereby is requested to prepare such papers and to take such steps with that end in view as may be proper.

Affirmative—The Mayor, the Comptroller, the President of the Board of Aldermen and the Presidents of the Boroughs of Manhattan, Brooklyn, The Bronx, Queens and Richmond—16.

In the Matter of the application of The City of New York to the State Water Supply Commission for the approval of the report of the Board of Water Supply of The City of New York to the Board of Estimate and Apportionment of The City of New York, dated June 8, 1908, recommending the development of the underground sources of water-supply in Suffolk county, Long Island, New York, and for the approval of the map, plan and profile accompanying said report and dated February 25, 1908, and entitled: "Board of Water Supply of The City of New York. Map and Profile Showing Manner of Obtaining from Suffolk County an Additional Supply of Water for The City of New York."	*Petition*

To the State Water Supply Commission:

The City of New York hereby respectfully makes application by petition in writing to the State Water Supply Commission, pursuant to the provisions of Chapters 723 and 724 of the Laws of 1905 and the acts amendatory thereof and supplemental thereto, and shows as follows:

(1) The City of New York is a municipal corporation organized and existing in the State of New York by virtue of its ancient charters and the Laws of the Colony of New York and the Laws of the State of New York.

(2) Pursuant to Chapter 724 of the Laws of 1905, and on or about June 9, 1905, the Mayor of The City of New York appointed J. Edward Simmons, Charles N. Chadwick and Charles A. Shaw to be a Board or Commission to be called Board of Water Supply of The City of New York. The said Commissioners duly qualified and entered upon the performance of their duties on or about the said date and have since continued to hold their said offices and to perform the duties thereof except that on January 28, 1908, the said J. Edward

Simmons resigned his said office and on January 30, 1908, John A. Bensel was appointed by said Mayor to act as such Commissioner, and on January 31, 1908, said John A. Bensel duly qualified and entered upon the discharge of his duties and has ever since continued to hold said office and perform the duties thereof.

(3) The Board of Water Supply proceeded pursuant to said statutes and made such surveys, maps, plans, specifications, estimates and investigations as they deemed proper in order to ascertain the facts as to what sources for an additional supply of pure and wholesome water for The City of New York exist and are most available, desirable and best for the said City, and under date of June 8, 1908, reported to the Board of Estimate and Apportionment of The City of New York recommending the development of the underground sources of water-supply in Suffolk county, Long Island, New York. A copy of said report is hereto annexed, marked " A," and is made a part of this petition. Accompanying said report was a map, plan and profile dated February 25, 1908, entitled " Board of Water Supply of The City of New York. Map and Profile Showing Manner of Obtaining from Suffolk County an Additional Supply of Water for The City of New York." Said map, plan and profile was duly signed by said Commissioners and their engineers. Said map, plan and profile and the other papers and documents accompanying this application form an exhibit of maps of lands to be acquired and profiles thereof showing the sites and areas of the proposed reservoirs and other works, the profiles of the aqueduct lines and the flow lines of the water when impounded, also plans and surveys and abstracts of official reports relating to the same, showing the need of The City of New York for the development of the underground waters of Suffolk county as a source of supply for The City of New York and the reasons therefor. This petition is accompanied by proof as to the character and purity of the water-supply proposed to be acquired.

(4) The Board of Estimate and Apportionment, upon the receipt of said report, map, plan and profile and prior to the adoption thereof, did afford to all persons interested a reasonable opportunity to be heard respecting the same and did give reasonable public notice of such hearing whereat testimony might be produced by the parties appearing in such manner as the Board of Estimate and Apportionment might determine.

On June 12, 1908, the Board of Estimate and Apportionment adopted a resolution in the following terms:

"Whereas, The Board of Water Supply of The City of New York, pursuant to Chapter 724 of the Laws of 1905, and the acts amendatory thereof and supplemental thereto, have made such surveys, maps, plans, specifications, estimates and investigations as they deemed proper in order to ascertain the facts as to what sources for an additional supply of pure and wholesome water for The City of New York exist and are most available, desirable and best for the said City; and

"Whereas, The said Board have reported to the Board of Estimate and Apportionment, under date of June 8, 1908, recommending the development of the underground sources of water-supply in Suffolk county, Long Island, New York; and

"Whereas, The Board of Water Supply have submitted with said report a map, plan and profile, dated February 25, 1908, and entitled 'Board of Water Supply of The City of New York. Map and Profile Showing Manner of Obtaining from Suffolk County an Additional Supply of Water for The City of New York'; now, therefore, be it

"Resolved, That the 26th day of June, 1908, at 10:30 o'clock in the forenoon, at Room No. 16, in the City Hall, Borough of Manhattan, City of New York, be fixed as the time and place for a public hearing upon the said report, map, plan and profile, and that notice be given of such public hearing by publication in the City Record, the corporation newspapers (published in Kings county), and in two newspapers published in each of the counties of Suffolk, Nassau, Queens, Richmond, New York and Westchester, said publication to commence Tuesday, June 16, 1908, and to be continued in each issue of each of said papers to and including June 26, 1908, the date hereby fixed for said hearing; such notice being hereby declared to be reasonable public notice of such hearing; and be it further

"Resolved, That the Secretary of this Board is hereby directed to give such notices as are provided for in said statutes and as he may be advised by the Corporation Counsel, with whom he is directed to confer in regard to this matter."

(5) Pursuant to the terms of said resolution a notice of said public hearing on June 26, 1908, was duly published in the City Record, and in the Brooklyn Daily Eagle, the Brooklyn Citizen, the Brooklyn Standard-Union, the Brooklyner

Freie Presse and the Brooklyn Times, being the corporation newspapers published in Kings county, and in the New York Herald and the New York Times, being two newspapers published in New York county, and in the Democratic Register of Ossining and in the Eastern State Journal, being two newspapers published in Westchester county, and in the Staten Island World and the Richmond County Herald, being two newspapers published in Richmond county, and in the Long Island City Star and the Jamaica Farmer, being two newspapers published in Queens county, and in the North Hempstead Record and the Republican, being two newspapers published in Nassau county, and in the Riverhead News and the County Review, being two newspapers published in Suffolk county. Notice of said public hearing on June 26, 1908, was also duly given pursuant to the provisions of Section 3 of Chapter 724 of the Laws of 1905, as amended, by mailing to the Chairman and Clerk of the Board of Supervisors of each county, where the real estate to be acquired is situated, a notice of such hearing at least eight days before the time named in the said notice, the said counties being Suffolk, Nassau and Westchester; said notices being also mailed to the President of the Board of Aldermen of The City of New York, and to the City Clerk of the City of New York, in behalf of the counties of New York, Kings, Queens and Richmond, there being no Board of Supervisors in any of said four counties. All of said facts will more fully appear from the records on file in the office of the Secretary of the Board of Estimate and Apportionment, all of which the petitioner herein begs leave to refer to and to produce.

(6) Said hearing before the Board of Estimate and Apportionment was duly had on June 26, 1908, at 10.30 o'clock in the forenoon, at Room 16, in the City Hall, Borough of Manhattan, City of New York, being the time and place duly set therefor. At said hearing the Board of Estimate and Apportionment, having heard all who appeared in opposition to the approval of the said report, map, plan and profile, and all who appeared in favor thereof, after due deliberation adopted a resolution approving and adopting the said report, map, plan and profile. Said resolution is as follows:

"Whereas, The Board of Water Supply of The City of New York, pursuant to Chapter 724, Laws of 1905, as amended, have made such surveys, maps, plans, specifications, estimates and investigations as they deemed proper in order to

ascertain the facts as to what sources where an additional supply of pure and wholesome water for The City of New York exist and are most available, desirable and best for the said supply; and

"Whereas, The said Board of Water Supply have reported to the Board of Estimate and Apportionment under date of June 8, 1908, recommending the development of the underground sources of water-supply in Suffolk county, Long Island, New York, and have presented to the Board of Estimate and Apportionment, with said report, a map, plan and profile dated February 25, 1908, and entitled 'Board of Water Supply of The City of New York. Map and Profile Showing Manner of Obtaining from Suffolk County an Additional Supply of Water for The City of New York;' and

"Whereas, The Board of Estimate and Apportionment upon the receipt of the said report and the said map, plan and profile, and on the 12th day of June, 1908, adopted a resolution that June 26, 1908, at 10.30 o'clock in the forenoon at Room 16 in the City Hall, Borough of Manhattan, City of New York, be fixed as the time and place for the public hearing upon the said report, map, plan and profile, and that notice be given of such public hearing by publication in the City Record and the corporation newspapers published in Kings county and in two newspapers published in each of the counties of Suffolk, Nassau, Queens, Richmond, New York and Westchester, such publication to commence Tuesday, June 16, 1908, and to be continued in each issue of each of said papers to and including June 26, 1908, such notice being by said resolution declared to be reasonable public notice of such hearing; and

"Whereas, The Board of Estimate and Apportionment in order to afford to all persons interested a reasonable opportunity to be heard respecting the said report, map, plan and profile, have given reasonable public notice of such hearing and in addition have given notice of such hearing by mailing to the Chairman and Clerk of each of the Boards of Supervisors of the counties where real estate to be acquired is situated, a notice of such hearing at least eight days before the 26th day of June, 1908, namely, to the Chairman and Clerk of the respective Boards of Supervisors of the Counties of Suffolk, Nassau, Westchester, and to the President of the Board of Aldermen of The City of New York, and to the City Clerk of The City of New York for the Counties of New York, Kings, Queens and Richmond; and

" Whereas, The said notice of said hearing was published in all of the papers specified and referred to above, being the City Record and the Brooklyn Daily Eagle, the Brooklyn Citizen, the Brooklyn Standard-Union, the Brooklyn Free Press and the Brooklyn Times, being the corporation newspapers published in Kings county, and in the New York Herald and New York Times, being two newspapers published in New York county, and in the Democratic Register, of Ossining, and in the Eastern State Journal, being two newspapers published in Westchester county, and in the Staten Island World and Richmond County Herald, being two newspapers published in Richmond county, and in the Long Island City Star and the Long Island Farmer, being two newspapers published in Queens county, and in the North Hempstead Record and the Republican, being two newspapers published in Nassau county, and in the Riverhead News and the County Review, being two newspapers published in Suffolk county, all of which is evidenced by the affidavits, certificates and documents filed in the office of the Secretary of the Board of Estimate and Apportionment; and

" Whereas, On the 26th day of June, 1908, at 10:30 o'clock in the forenoon in Room 16 in the City Hall, Borough of Manhattan, City of New York, the Board of Estimate and Apportionment met, pursuant to said notice and a public hearing was given to all persons interested and a reasonable opportunity to be heard respecting the said report, map, plan and profile was afforded to such persons, at which hearing the said report, map, plan and profile were considered and due deliberation was had; and many having appeared in opposition to said report, map, plan and profile, and also many in favor thereof; now, therefore, be it

" Resolved, That the Board of Estimate and Apportionment hereby approves and adopts the said report, dated June 8, 1908, and the said map, plan and profile, dated February 25, 1908, and hereby directs that the said map, plan and profile be executed, signed, certified and filed as directed in Section 3 of Chapter 724 of the Laws of 1905, as amended, and hereby declares the same to be the final map, plan or plans and profile approved and adopted by the Board of Estimate and Apportionment as provided for in said section; and be it further

" Resolved, That the said Board make application by petition in writing to the State Water Supply Commission as

speedily as possible for the approval of the said report, map, plan and profile, pursuant to Chapter 723, Laws of 1905, as amended, and that the Corporation Counsel be and he hereby is requested to prepare such papers and to take such steps with that end in view as may be proper."

(7) After the approval and adoption of said report, map, plan and profile, the said map was duly executed in quadruplicate. One thereof accompanies this petition and is intended to be filed herewith and made a part hereof. A second remains on file with the Clerk of the Board of Estimate and Apportionment. A third is placed on file in the office of the Board of Water Supply. A fourth is filed in the office of the Commissioner of Water Supply, Gas and Electricity of The City of New York. A certified copy of said map is filed in the office of the County Clerk or Register of each of the counties in which the real estate affected thereby is situated. A copy of the said report of the Board of Water Supply of The City of New York to the Board of Estimate and Apportionment, dated June 8, 1908, is also herewith presented, together with an abstract of official reports relating to the development of the underground waters of Suffolk county, and showing the need for the development of said sources for The City of New York and the reasons therefor. In addition, The City of New York herewith presents a plan or scheme to determine and provide for the payment of the proper compensation for any and all damages to persons and property, whether direct or indirect, which will result from the acquiring of said lands and the execution of said plans. All of said matters will be more fully shown in the proceedings, papers and documents which will be produced at the hearing before the State Water Supply Commission.

(8) The proposed development of the underground sources of water-supply in Suffolk county and the execution of the plans herewith presented are justified by public necessity and are just and equitable to the other municipalities and civil divisions of the State affected thereby and to the inhabitants thereof, particular consideration being given to their present and future necessities for sources of water-supply.

(9) The plan or scheme to determine and provide for the payment of proper compensation for any and all damages to persons or property, whether direct or indirect, which will result from the acquiring of the said lands and the execution

of the said plans, is to purchase the said lands and to secure conveyances and releases thereof if the amount can be agreed upon, and if not to acquire the same by condemnation proceedings, as provided in Chapter 724 of the Laws of 1905 and the acts amendatory thereof and supplemental thereto. The City of New York is of abundant financial responsibility to pay any and all of the aforesaid damages and the Board of Estimate and Apportionment of The City of New York has unanimously approved the report of the Board of Water Supply of The City of New York setting forth the estimated cost of the whole project of developing the underground sources of water-supply of Suffolk county, in order to provide means for paying all just claims which may arise against it, growing out of the construction of the necessary works and the acquisition of the necessary lands. It is proposed to pay all such claims from the proceeds of Corporate Stock to be issued from time to time by the Comptroller when thereto authorized by the Board of Estimate and Apportionment.

Wherefore, The City of New York hereby makes application by petition in writing to the State Water Supply Commission for the approval of the said report, map, plan and profile, and has caused this petition to be subscribed by its acting Mayor and by its City Clerk and its seal to be affixed hereto this 28th day of July, 1908.

P. F. McGOWAN,
Acting Mayor.

(L. S.)

P. J. SCULLY,
City Clerk.

WM. P. BURR,
Acting Corporation Counsel.

State of New York, }
County of New York, } ss.:
City of New York, }

On the 28th day of July, in the year 1908, before me personally came P. J. Scully, with whom I am personally acquainted, and who is known to me to be the City Clerk of The City of New York, who being by me duly sworn did depose and say:

I reside in the Borough of Manhattan, City of New York. I am City Clerk of The City of New York, the corporation described in and which executed the foregoing petition. I know the seal of said corporation. The seal affixed to said petition is such corporate seal. It was thereto affixed by due authority of said corporation, and I signed my name thereto as City Clerk by like authority. I know Patrick F. McGowan and know him to be the person described in and who as Acting Mayor of The City of New York executed said petition. I saw him subscribe and execute the same, and he acknowledged to me, the said P. J. Scully, that he executed and delivered the same, and I thereupon subscribed my name thereto.

JOHN H. GAMALDI,
Notary Public,
New York County.

Babylon, N. Y., February 25, 1908.

J. Waldo Smith, Esq.,
Chief Engineer, Board of Water Supply,
299 Broadway,
New York City.

Sir:

In accordance with your instructions, the following report is submitted on the water-supply sources of Long Island, with particular reference, first to the immediate need of an additional supply for the Borough of Brooklyn; second, to the amount of water available from the present sources of supply; and third, to the yield and the probable cost of developing the Suffolk County ground-waters.

The needs of Queens borough have not been considered in detail in this report. While this part of the City is, in some districts, imperfectly supplied with water, there appears to be sufficient area within the borough from which to draw all the water that may be required during the next few years, until a large supply can be introduced from the Catskill or from the Suffolk County sources.

This report embodies the results of studies and investigations that have been made under your direction since the organization of the Long Island department in October, 1906.

CONCLUSIONS IN BRIEF

If the present annual increase in the consumption of water in Brooklyn continues, this borough, the second largest in New York City, must soon face a serious water famine. Frequent shortages in supply have indeed taken place since the introduction of a public water-supply in 1858, notably in the fall of 1905, when the higher portions of the borough suffered severely from lack of water. All efforts made at such times to curtail the waste in the distribution system have not prevented a steady increase in the use of water. Prompt measures must therefore be taken at once to increase the water-

supply of Brooklyn if great hardship or even disaster is to be averted.

Yield of Present Brooklyn Water-Works

The average daily supply of water furnished the Borough of Brooklyn in 1907 from all municipal and private sources was 145 million gallons, of which 85 per cent. was supplied by the Ridgewood system from southern Queens and Nassau county and 15 per cent. by small private and municipal works within the borough limits. The estimated population of Brooklyn borough is 1,470,000, so that the per capita consumption is now 98.6 gallons per day.

This is less than that of the other large boroughs of the City, and may be accounted for by the relatively smaller transient population, the insufficient water-supply of the past years and the reduced pressure that has been maintained in the mains of the distributing system.

The present municipal and private water-works cannot safely yield during a period of years of even normal rainfall more than 135 million gallons per day. *If the next few years be a period of deficient rainfall, these works should not be expected to provide over 120 million gallons per day.*

The term "safe yield," as applied to the collecting works of the Brooklyn system in southern Long Island, is intended to mean that portion of the natural seaward flow of the water from the upland watersheds that may be intercepted without overdrawing storage or pumping in sea-water from the adjacent bays through the porous sands and gravels. The yields given on this and succeeding pages are intended to be conservative; larger yields may be obtained, but at the expense of reducing the future yield and impairing the quality of the supply.

Works Now Being Constructed

With the additional works which are now under construction by the Department of Water Supply, and which should be completed before the end of the present year, the total supply of Brooklyn borough for years of normal rainfall will be increased to 160 million gallons per day.

During years of low rainfall, however, the entire system, including the new works, cannot be depended upon to supply more than 140 million gallons per day. This is evidently less than the consumption of Brooklyn borough in 1907.

Total Yield of Readily Available Sources in Western Long Island

By the more complete development of the ground-waters of the Ridgewood system and the construction of three additional driven-well stations in Brooklyn borough, it would be possible to so increase the present supply that there would be available, during years of normal rainfall, a total supply of 195 million gallons per day.

This supply would provide for the natural increase in the consumption of Brooklyn borough up to the year 1913, if this increase continues at the present rate. *Should, however, a period of low rainfall now ensue, the complete works might not yield more than 170 million gallons per day,* which at the present rate of increase in consumption would not suffice beyond the year 1910.

Relief from New Sources in 1912

Under the most favorable circumstances that may reasonably be expected, with a normal rainfall and the immediate construction of works to develop the entire yield of the available sources in western Long Island, the continued increase in consumption at the present rate demands the introduction of an additional supply of water into Brooklyn borough from new sources by the year 1912. If, however, a series of dry years should occur, some additional water must be supplied by the year 1910.

The Catskill sources cannot be made available in time to avert this impending shortage of water, since the first supply from the works now under construction can hardly be delivered to the Borough of Brooklyn before 1916, and, perhaps, not until several years later.

Suffolk County Ground-Water Sources

If the ground-waters of Suffolk county were available, they could be cheaply and quickly developed to provide an emergency supply for the relief of Brooklyn borough, and they could be made to eventually furnish to New York City a large permanent supply of excellent water for domestic and commercial uses.

An average supply of 250 million gallons per day could safely be obtained from a catchment area of 332 square miles

in southern Suffolk county and the Peconic valley. This supply could be appropriated from the large volumes of ground-water now running to waste there, without material injury or annoyance to local interests. The total cost of the works to obtain this supply, delivered into the distribution system of Brooklyn borough, is estimated at $47,173,000.

The works in southern Suffolk county would be built from Amityville to Quogue on a line nearly parallel with the south shore of Long Island, somewhat back from the populous villages and the salt waters of the south shore bays, in country but sparsely settled, and covered to a large extent with low growths of scrub oak and pine. The ground-waters would be gathered on this line by means of suitable wells, 100 to 200 feet in depth, and 500 to 1,000 feet apart, which would be driven in the center of a right-of-way 600 to 1,000 feet wide. The supply from the Peconic valley would be similarly collected on the south bank of the Peconic river between Riverhead and Calverton. This supply would be pumped over to the south shore and conveyed to the City, mingled with the waters of southern Suffolk county, in a continuous gravity aqueduct of concrete masonry. A large pumping-station at the end of this aqueduct, near the present Ridgewood pumping-station, in Brooklyn borough would deliver the supply into a covered distributing reservoir or directly into the City mains.

When these works are completed and the demand for water in the City approaches the average yield of the Suffolk County watersheds, it is proposed, later, to construct three branch lines into the center of the island to secure storage from the deep gravels there, in order to avoid pumping the wells deeply on the main south shore line, during periods of deficient rainfall.

Works to Be Built First

The complete works outlined above, for the development of the entire water-supply need not be built for some years. For the present, it is proposed to construct only the first 15 miles of the collecting works in Suffolk county as far as Great River to secure a supply of 70 million gallons per day, and the transportation works by which to deliver this supply to the distribution system of Brooklyn borough. The works at this first stage of construction, including the large masonry aqueduct of full capacity for the final development, are estimated to cost $21,742,000, and could be completed within three

or four years after beginning work. The remainder of the works would be built by successive stages at intervals of five or six years, as the supply is needed to meet the increasing consumption of the City.

Emergency Supply from Suffolk County

A portion of the first supply of 70 million gallons per day might even be delivered to Brooklyn borough within two years from the time of beginning work in Suffolk county, if, at the end of that period, the Department of Water Supply has completed the proposed extension of the 72-inch pipe-line and built the proposed pumping-stations at Massapequa and Wantagh. By first building the Suffolk County aqueduct from the new gathering grounds to Massapequa, and utilizing from Massapequa to Brooklyn the surplus capacity of the new transportation works proposed by the Department of Water Supply, for which plans are already made, an emergency supply of perhaps 50 million gallons per day could be delivered from Suffolk County two years before the long masonry aqueduct to Brooklyn could be finished. It is estimated that the Suffolk County works, at this preliminary stage of construction would cost, exclusive of the proposed expenditures of the Department of Water Supply, $7,153,000.

Cost of Suffolk County Supply

The estimates on the amount of water that would be available, the total expenditure at each stage of construction, and the cost of the water per million gallons delivered into the mains of Brooklyn borough are shown below:

Stage of Construction	Average Supply in Million Gallons Per Day	Total Estimated Cost of Works at this Stage	Cost of Water Per Million Gallons Delivered in Brooklyn Borough
Preliminary........	50	$7.153,000	*$37.78
1..................	70	21,742,000	**62.21
2..................	150	30,262,000	44.53
3..................	220	38,355,000	40.12
4..................	250	40,479,000	39.24
5..................	250	47,173,000	44.18

*This cost does not include fixed charges on the pumping-stations and the steel-pipe line proposed by the Department of Water Supply

**The high cost of the water in the first stage of the complete works is due to the large fixed charges on the masonry aqueduct of 250 million gallons daily capacity, from Suffolk county to Brooklyn borough

Aqueducts of Full Capacity for Development of 250 Million Gallons per Day

The future supply of Brooklyn, as well as that of Queens borough and other portions of New York City, may be best safeguarded by constructing the aqueducts in the first Suffolk County works of full capacity as suggested above so that they may be extended as required, to collect and transport to the City the entire available supply in Suffolk county. Neither a smaller permanent development nor temporary works in Suffolk county should be considered.

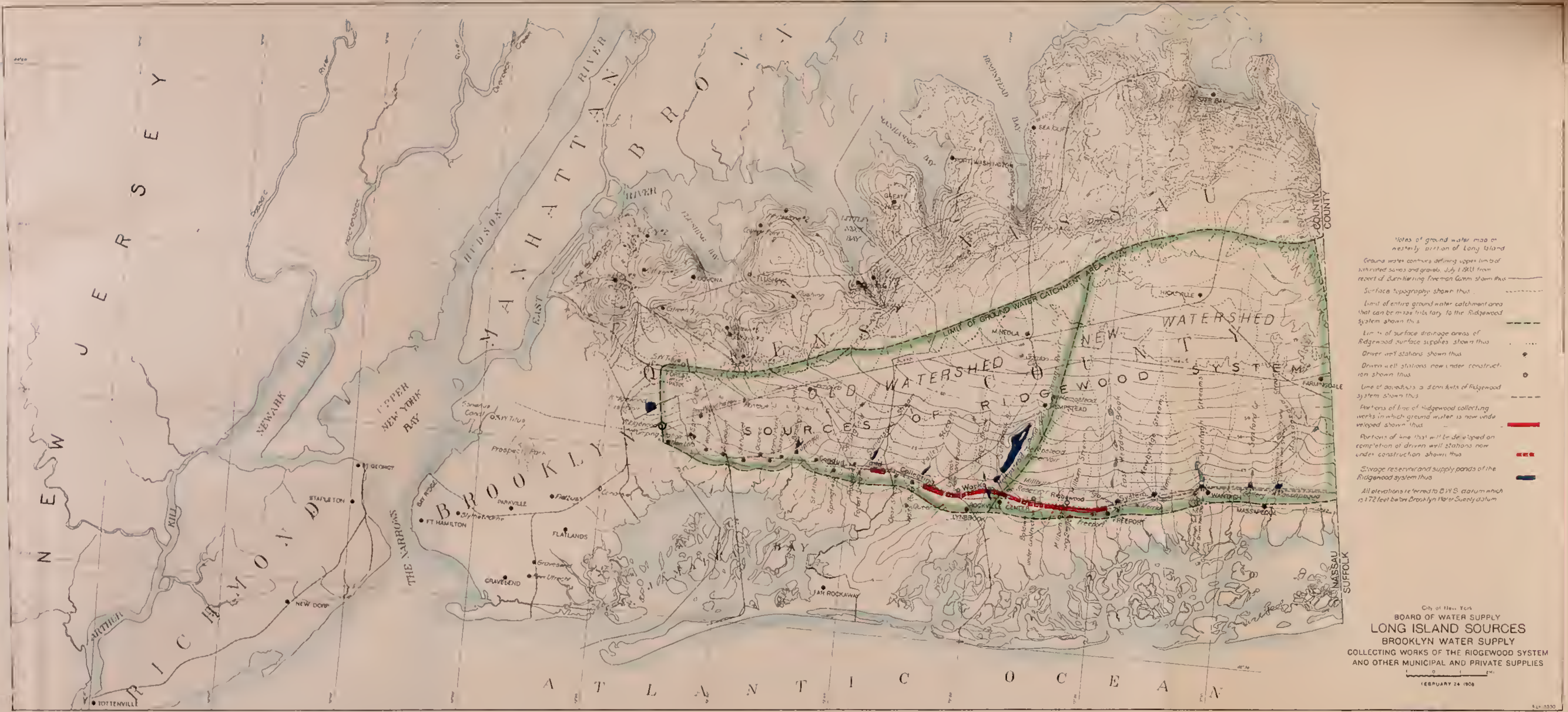
The amount of money that might be saved in fixed charges by now building an aqueduct of only 150 million gallons daily capacity, would not be sufficient at the end of 20 years to build another of a capacity of 100 million gallons per day. Neither would it pay to build temporary works in Suffolk county for the delivery of 50 million gallons per day through the conduits of the Ridgewood system, unless only a temporary supply is to be drawn from Suffolk county.

If the population and water consumption of New York City continues to increase at the present rate, the entire supply from existing works and the additional 500 million gallons per day from the Catskill sources will be required in about 20 years. If not developed now, the Suffolk County sources would naturally be drawn upon at that time. Some water, however, must be secured at once from Suffolk county to relieve the imminent shortage in the supply of Brooklyn borough. In view of the inadequacy of the water-supply of this part of the City for many years, and the large resident population that is likely to develop in the Long Island boroughs of The City during the next ten years, as a result of the improved transit facilities now being provided, it seems very likely that, even with the water from the Catskill sources, the first supply of 70 million gallons per day from Suffolk county would be needed continuously until an additional supply for the City was required. This is rendered more probable by the likelihood of some of the ground-water and surface supplies in western Long Island being abandoned in a few years in consequence of the infiltration of sea-water and the increase in the population on their gathering grounds.

PRESENT SUPPLY OF BROOKLYN BOROUGH

The Borough of Brooklyn is supplied with water from the works of the Ridgewood system in Queens and Nassau coun-

SHEET 1



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ties, and from several small municipal and private water-works located within the borough limits.

THE RIDGEWOOD SYSTEM

The Ridgewood system furnishes about 85 per cent. of the present water-supply of Brooklyn from the streams and the ground-water works along the south shore of Long Island in Queens and Nassau counties, between the limits of Brooklyn borough and the Suffolk County line.

Area of Watershed

The watershed of the Ridgewood system, defined by the limits of the ground-water catchment, is shown on Sheet 1, Acc. 5530. This watershed, which represents the total catchment that might, by a complete development, be made tributary to the Ridgewood system, has an area of 159 square miles, of which 67 square miles may be apportioned to the "old watershed," and 92 square miles to the "new watershed."

The southerly limit of the catchment area represents the greatest safe inflection of the ground-water surface during long periods of heavy draft at all driven-well stations, with a complete development of the system. Where there are no ground-water collecting works, the limit of the catchment area is at the spillways of the supply ponds, and, for the greater part of the time, the existing ground-water works do not ordinarily inflect the water-table as far south as shown.

The flow of all but a few unimportant streams within this catchment area has been made tributary to the system. It is estimated that the total surface drainage area of these streams, south of the ground-water divide, is 117 square miles. Of this area, the streams in the "old watershed" drain 52 square miles, and those in the "new watershed" 65 square miles.

The ground-water underflow on the line of collecting works has not yet been entirely developed by The City. For a distance of slightly less than eight miles along the conduit line, as shown by the band of red on Sheet 1, Acc. 5530, only surface-waters are collected. Upon the completion of the new driven-well stations at Lynbrook and Millburn reservoir, about 1½ miles more of this line will have been developed. Water can hardly be drawn from about 1½ miles of the remaining line, within the villages of Rockville Center and Free-

port, but there will still be about five miles along which ground-water may be collected.

Present Yield of Works

The yield of the collecting works of the Ridgewood system for the past three years is shown in Table 1, which has been compiled from the records in the office of the Department of Water Supply at Brooklyn. The year 1905 was one of low rainfall, only 36.8 inches being recorded at Hempstead storage reservoir. The next year, 1906, in which 44.1 inches fell at the same station, was one of nearly normal rainfall, while during the past year, 1907, a rainfall of 49.4 inches, something over 5 inches in excess of the normal precipitation, occurred in western Long Island.

The period of operation of the driven-well stations during these years was dependent upon the consumption and the yield of the surface streams. During the early part of 1905 and the greater part of 1907, the surface-waters formed a large proportion of the total supply, but during the greater part of 1906, it was necessary to utilize the maximum available yield of the ground-water stations.

The last column of this table gives the probable safe yield of each driven-well station and infiltration gallery of the Ridgewood system and the probable delivery of each tributary surface stream when the ground-water collecting works are operated at these rates, during the summer and fall of normal rainfall years.

The total safe yield of the watershed is estimated as follows:

New Watershed, 92 square miles..	62	million	gallons	per	day.
Old Watershed, 67 " " ..	55	"	"	"	"
Total yield of system.....	117	"	"	"	"

The relatively smaller yield of the new watershed is due to the incomplete development of the ground-waters, as already noted. These estimates of yield of each source of supply have, so far as possible, been corrected for the loss of surface-water that takes place in leakage from the brick conduits and which appears in the pumping records as ground-water

TABLE 1

YIELD OF COLLECTING WORKS OF RIDGEWOOD SYSTEM.

Surface and Driven Well Sources.	1905 Approx. Period of Draft in Months.	1905 Average Yield During This Time in Mil. Gals. Dly	1906 Approx. Period of Draft in Months	1906 Average Yield During This Time in Mil. Gals Dly	1907 Approx. Period of Draft in Months.	1907 Average Yield During This Time in Mil. Gals Dly	Estimated Safe Yield of Each Source During Years of Normal Rainfall, M.G.D.
	NEW WATERSHED						
Massapequa Gallery	0.5	7.7	9.5	12.7	10.5	15.7	15.0
" Stream*	—	—	—	—	—	—	3.0
" D.W.S.	6.5	36	10.0	2.5	7.0	2.7	2.0
Wantagh Stream*	—	—	—	—	—	—	3.0
Gallery	7.5	7.1	12.0	11.5	8.0	12.1	10.0
D.W.S.	5.5	2.6	10.0	2.8	6.0	2.8	3.0
Matowa D.W.S.	7.5	3.3	10.0	2.8	6.0	2.6	3.0
Newbridge Stream*	—	—	—	—	—	—	2.0
Merrick D.W.S.	5.5	3.8	8.5	3.6	7.0	3.6	4.0
East Meadow Stream*	—	—	—	—	—	—	9.0
Agawam D.W.S.	5.0	3.1	8.0	2.7	6.0	2.5	3.0
Millburn Stream*	—	—	—	—	—	—	5.0
Gravity Supply from New Watershed	—	40.2	—	26.7	—	34.6	—
Total New Watershed	—	—	—	—	—	—	62.0
	OLD WATERSHED						
Horse Brook	11.0	1.4	10.0	1.2	10.0	1.1	
Smiths Pond	11.0	10.1	11.0	9.0	11.0	8.9	
Hempstead Storage+	—	—	—	—	—	—	10.0
Schodack Brook+	—	—	—	—	—	—	
Pines Stream+	—	—	—	—	—	—	
Watts Pond D.W.S. / " " Stream	12.0	5.0	11.5	4.4	11.0	4.7	4.0
Valley Stream+	—	—	—	—	—	—	
Clear Stream D.W.S.	12.0	2.4	11.0	2.9	11.0	2.7	3.0
Forest Stream D.W.S.	11.5	3.5	12.0	3.6	10.5	4.3	3.0
Simonsons Stream	10.0	3.5	9.5	2.8	9.0	3.1	3.0
Rosedale D.W.S.	—	—	6.0	2.5	11.0	3.4	3.0
Springfield D.W.S.	12.0	2.9	11.5	2.6	11.0	2.7	2.5
" Stream	9.5	2.6	6.0	2.8	5.0	2.1	1.0
St. Albans D.W.S.	—	—	6.0	2.5	11.5	2.6	2.0
Jameco D.W.S.	12.0	3.3	12.0	5.3	11.5	7.7	5.0
Baiseleys Stream	11.5	4.5	10.0	4.0	11.5	2.8	2.0
" D.W.S.	11.0	1.6	11.5	1.7	10.0	0.8	1.0
Morris Park	—	—	—	—	8.0	3.9	2.0
Oconee	11.0	3.0	11.0	3.3	9.0	3.9	3.0
Shetucket	6.0	0.5	—	—	5.0	3.9	2.0
Aqueduct	—	—	6.0	4.4	11.5	4.2	2.0
Woodhaven	—	—	—	—	3.5	3.8	2.0
Spring Creek	11.0	4.6	11.0	6.7	11.5	5.1	4.5
Gravity Supply from Old Watershed	—	13.2	—	3.0	—	−1.7	—
Total Old Watershed	—	—	—	—	—	—	55.0
Total of Old & New Watersheds	—	—	—	—	—	—	117.0

B.W.S. 446

* Included in gravity supply from new watershed pumped at Millburn Pumping Station

\+ Included in gravity supply from old watershed pumped at Ridgewood Pumping Station.

yield. All errors of pump displacement and leakage from conduits are charged in the records of the Department of Water Supply against the gravity surface supply, and, in general, the surface gravity yield given in the records is above the true yield for the new watershed, and is below that for the old watershed. The probable error in the estimates of the yield of the Ridgewood system is between 5 and 10 per cent. and is generally within the smaller figure.

A larger supply than is here shown may sometimes be drawn from the surface streams in winter and spring, but as the system has no storage for surface-waters, such as is ordinarily provided for surface-water supplies, except that in the Hempstead storage reservoir and in the shallow supply ponds, some waste occurs. The large winter stream flow of wet years cannot, therefore, be considered in the estimate of the safe summer yield, excepting as this flow at times permits the draft on the ground-water to be diminished, and the storage in the pore spaces of the sands and gravels to be replenished for the heavy draft of summer and fall.

If the ground-water stations of the Ridgewood system are operated continuously during years of normal rainfall, only a small portion of the rainfall, on even the largest streams, appears as surface flow. During the winter and spring it has been the practice to reduce the rate of pumping at the ground-water stations, in order to utilize this surface flow as far as possible without pumping and to replenish the ground-water reservoirs. With an increase in the pollution of the surface-waters of the Ridgewood system, it will be necessary to filter them, and this cannot be better accomplished than by operating the ground-water stations continuously at a rate that will develop these surface-waters as artificial ground-water.

The normal delivery of some of the driven-well stations has been estimated in the table as less than the average draft during the past few years, because it is believed that these stations will not safely deliver continuously their present yields. This applies particularly to Spring Creek (shallow well), Baisley's and Jameco (shallow well) stations, the supplies from which have, at times, contained a comparatively large amount of salt water. The amount of sea-water, as represented by the chlorine in the water pumped at the Aqueduct and Morris Park stations, is not yet high enough to

increase materially the salinity of the whole supply, but it is very likely that some reduction must eventually be made in their present rate of pumpage.

Additional Supply from Stations under Construction

It is estimated that the two additional driven-well stations which are now under construction by the Department of Water Supply, the "*Lynbrook station" and the "Baldwin station" at the Millburn reservoir, will each yield a safe supply of five million gallons per day, which will make the safe normal yield of the Ridgewood system 127 million gallons per day.

During a period of low rainfall years, the amount of surface and ground-water reaching the system will diminish, and the pumpage of some of the stations affected by salt water might necessarily be reduced. With all the ground-water storage available, the system would not probably supply more than 115 million gallons per day.

The safe normal yield of the Ridgewood system, as given above, upon the completion of the two additional stations, is shown in a mass curve on Sheet 2, Acc. LJ 147. The red shading shows the probable reduction in the yield during years of low rainfall.

Total Additional Supply from Ridgewood System

By the construction of eight additional stations at points on the conduit line where the ground-water is now undeveloped, a further daily supply of 27 million gallons of ground-water might be obtained, as follows:

Location of stations	Probable yield in million gallons per day
Between Forest stream and Clear stream.......	2
**Between Watt's pond and Lynbrook.........	3
**Between Lynbrook and Smith's pond........	2
At Smith's pond............................	5

* Following a decision of the Supreme Court noted in foot-note following, an agreement was made with the Queens County Water Company, limiting the yield of the Lynbrook station to 1.5 million gallons per day.

** Since this report was submitted, a decision of the Appellate Division of the Supreme Court, Second Department, on March 5, 1907, has given the watershed between Watts Pond station and Smith's pond to the Queens County Water Company and excluded The City from further development, so that the above stations proposed between Watts pond and Lynbrook and Lynbrook and Smith's pond cannot be constructed.

Location of stations	Probable yield in million gallons per day
Between Rockville Center and Millburn reservoir	4
Between Millburn reservoir and Millburn station	4
At Millburn pumping-station	5
Between Freeport and Agawam station	2
Total	27

The operation of these stations would doubtless decrease the surface yield of Pine stream, Hempstead stream and Millburn stream, so that the net additional supply from the new stations would only be about 22 million gallons per day. The cost of these stations, including land and water damages, is estimated at $900,000.

By driving additional deep wells and connecting up the existing ones at Wantagh and Massapequa, and by driving shallow wells at Springfield, a further supply of 6 million gallons per day could be obtained. This, with the additional supply of 22 million gallons per day from new stations, would increase the yield of the Ridgewood system by 28 million gallons per day.

These new stations would intercept the ground-water movement along the entire line of collecting works from Spring creek to the Suffolk County line, except for a short distance in the villages of Rockville Center and Freeport, and a total supply could be drawn from the system during years of normal rainfall, of 155 million gallons per day. This would probably be reduced, after several years of low rainfall, to a supply not greater than 140 million gallons per day.

The total safe yield of the entire Ridgewood system during years of normal rainfall, after the completion of the eight new stations and the additional wells here suggested, is shown in the mass curve on Sheet 2, Acc. LJ 147. The blue shading indicates the probable reduction in the yield of the system during periods of low rainfall.

Capacity of Conduits

The construction of additional ground-water pumping-stations on the Ridgewood system has been governed somewhat,

in past years, by the location and capacity of the conduits through which the water could be delivered to Brooklyn borough, and the relation of the yield of the watershed to the present conduit capacity should be understood.

The conduit system in the "new watershed" consists of a brick aqueduct from the Massapequa pond to the Millburn pumping-station, in which the yield from the four supply ponds and the ground-water collecting works of the new watershed is delivered by gravity to the Millburn pumping-station.

At this point the supply is pumped into three 48-inch mains, of which two are laid directly to the Ridgewood pumping-station. The third goes to the west gate-house of Millburn reservoir where it is reduced to a 36-inch main, which continues to the brick conduit at Smith's pond.

This is the "old conduit" originally constructed between Hempstead pond and the Ridgewood pumping-station, to carry, by gravity, the surface and underground waters collected on the old watershed.

A 72-inch steel-pipe line, designed to be operated under the full distribution pressure, has been laid from a point about 3000 feet west of the Ridgewood station to the Clear Stream pumping-station. A 48-inch main connects this 72-inch line with the Ridgewood pumping-station and a 20-inch branch line has been laid to the New Lots station. The Water Department proposes to extend the 72-inch pipe, full size, to the Suffolk County line.

It is proposed to utilize the 72-inch line, which has a capacity of 50 million gallons per day, on a pumping gradient of 2.2 feet to the mile, to convey the water from the infiltration galleries and other sources in the new watershed, and it is planned that pumps would be installed at Massapequa and Wantagh to deliver the water directly into the distribution system. The extension of this 72-inch line to Massapequa would relieve both the old and the new brick conduits of approximately 30 to 50 million gallons per day.

The cost of the extension of this pipe-line and the pumping-stations proposed is estimated by the Department of Water Supply as follows:

72-inch pipe-line, 15.7 miles in length..........	$3,000,000
Right-of-way 100 feet wide through the villages and 200 feet wide elsewhere, including damages	1,000,000
2 pumping-stations of 70 million gallons total daily capacity	850,000
Total	$4,850,000

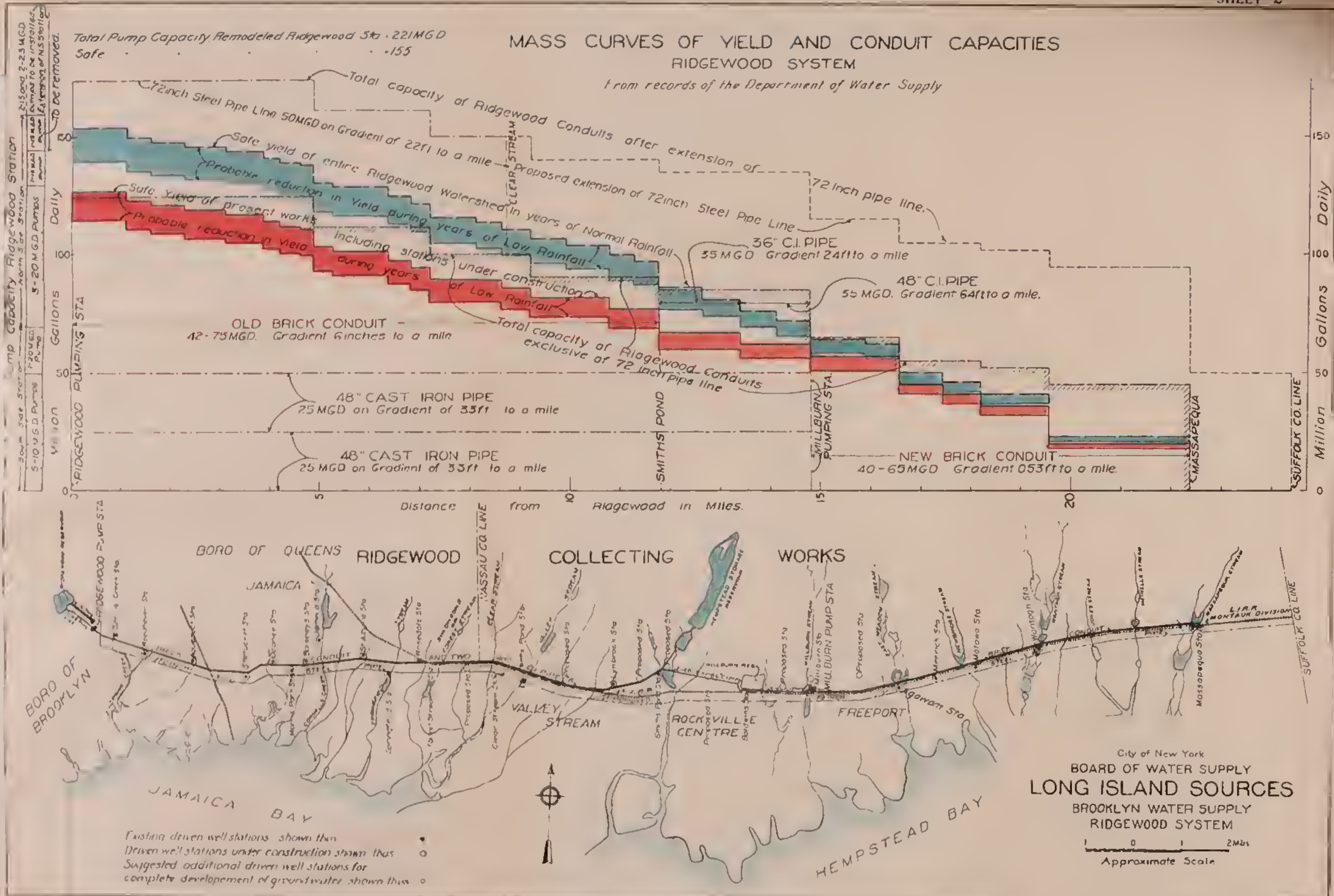
Sheet 2, Acc. LJ 147, shows the normal capacities of all the aqueducts and pipe-lines of the Ridgewood system and the relation of the total conduit capacity to the present and the possible future supply. From this diagram it appears that east of Clear stream, the present easterly end of the 72-inch pipe line, some additional conduit capacity is necessary for the safe operation of the system when completely developed. The large capacity that would be provided in the new watershed by the extension of the 72-inch pipe-line, would permit of carrying to the City a volume of water from the surface streams and the ground-water stations in the easterly portion of the system, much in excess of their average yield, when it is desired to reduce the delivery of the old watershed for the purpose of making repairs or filling the depleted ground-water reservoirs.

The masonry aqueduct of 250 million gallons daily capacity, here proposed for the Suffolk County works, could not be built from Ridgewood, or even from Clear stream, to the Suffolk County line by the year 1910, when the full yield of the Ridgewood system may be needed. There is, therefore, no possibility of safely omitting the extension of this 72-inch steel pipe, if the full yield of the Ridgewood system is to be made available in 1910. This conduit and the proposed pumping-stations at Massapequa and Wantagh should, therefore, be constructed immediately.

Capacity of Pumping-Plants

The pumping-plants of the Ridgewood system may be divided into three groups, i.e., ground-water and pond stations, intermediate stations, and main stations.

At the ground-water and pond stations in the watershed,



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there is sufficient pumping capacity to deliver the available supply from each station.

At Millburn pumping-station, the only intermediate station, the entire yield of the new watershed is raised about 50 feet to give the necessary head to deliver the water to Ridgewood station and to the old conduit. The equipment consists of five pumps, each delivering 10 million gallons per day, and two of 12½ million gallons daily capacity, which can readily handle the full discharge of the new brick conduit, about 60 million gallons daily.

The water pumped at the proposed Massapequa and Wantagh stations into the extension of the 72-inch pipe-line would be delivered directly into the distribution system.

The entire supply drawn from the old and new watersheds is now pumped at the Ridgewood station, the main pumping-station of the system. This station is divided into two plants, one to the north and the other to the south of Atlantic avenue. The north side plant, or the "old station," is at present being remodeled. When this work is completed, it will contain three pumps having a daily capacity of 15 million gallons, three of 20 million gallons and two of 23 million gallons, a total of 151 million gallons per day. The south side station, the so-called "new station," has an equipment of five pumps, each of 10 million gallons daily capacity, and one of 20 million gallons per day, giving a total of 70 million gallons daily.

The pumps of the south side station are frequently in need of repairs and the safe capacity of the station should not be estimated above 50 million gallons per day. The north side station is planned to pump against the Mt. Prospect Reservoir and Tower services as well as the Ridgewood Reservoir head and because of this arrangement, its safe capacity, when remodeled, cannot be placed above 113 million gallons per day. Under the most economical conditions of operation, however, this would not be over 105 million gallons per day, so that the total safe capacity of the entire Ridgewood station may be placed at 155 million gallons per day.

The total capacity of the conduits feeding the Ridgewood station is now 125 million gallons per day, exclusive of the 48-inch pipe from the end of the 72-inch steel-pipe line. The safe pumping capacity at this station after remodeling will, therefore, be 30 million gallons per day in excess of the conduit capacity.

The Mt. Prospect station has two pumps of a total capacity of 9 million gallons per day for the Reservoir service, and three pumps of a total capacity of 13 million gallons per day for the Tower service. These pumps draw their supply from the distribution mains of the Ridgewood Reservoir service and should be abandoned when the new pumps are completed at Ridgewood, and the necessary additional force mains are installed.

The plans of the Department of Water Supply include new pumping-plants for the Massapequa and Wantagh infiltration gallery stations. These plants would consist of high duty pumps, capable of delivering the water into the distribution system against the head of the Ridgewood service. The supply would be drawn from the infiltration galleries and also from the "new brick" conduit, through suitable connections. The water would be discharged into the 72-inch steel-pipe line, through which it would be carried to the distribution mains.

Assuming these proposed stations to have a combined safe pumping capacity of 50 million gallons per day and adding this amount to the safe pumping capacity at the Ridgewood station, the sum would represent the total safe capacity of the Ridgewood system to deliver water to the distribution system as follows:

Ridgewood station, when remodeled..	155	million	gallons	daily
Proposed Massapequa and Wantagh stations	50	"	"	"
Total	205	"	"	"

As the estimated safe supply from the Ridgewood watershed during years of normal rainfall is only 155 million gallons per day, there would be an excess of 50 million gallons per day in the safe pumping capacity.

OTHER LONG ISLAND SOURCES OF SUPPLY FOR BROOKLYN BOROUGH

About 15 per cent. of the water now consumed by Brooklyn borough is supplied by several driven-well stations in the borough limits, belonging to The City and to private water

companies, which are shown below with their probable safe normal yield:

Present and Proposed Sources	Safe Normal Yield in million gallons per day
City stations	
New Lots	5
Gravesend	3
New Utrecht	1
Canarsie (under construction)	5
Private stations	
Flatbush Water Works Co.	5
Blythebourne Water Co.	3
German-American Improvement Co.	1
Total City and private stations	23

In addition to the above plants, a station has been partially constructed by S. W. Titus in Brooklyn borough in the vicinity of Sixth street and Fourth avenue, near the Gowanus canal, under a contract with The City, calling for the delivery of not less than five million gallons per day. A second station is being constructed by Titus under the same contract and with the same stipulation of minimum yield at a location in Queens borough north of Forest park, as shown on Sheet 1, Acc. 5530.

The first station is so near the salt water of New York bay that it does not seem probable that more than two million gallons per day can be pumped continuously without the infiltration of salt water, even if the drainage from the densely populated watershed surrounding the station does not so increase the mineral content of the supply as to render it unfit for use.

The station north of Forest park is on the summit of the water-table where the magnitude of the tributary catchment area depends upon the depth of pumping. After the storage of years has been abstracted from the pore spaces of the underlying material, it is not believed that this station will yield more than eight million gallons per day.

Allowing a safe average yield of 10 million gallons per day from these two stations of Titus, the total delivery from sources outside of the Ridgewood system, including the 23 million gallons per day from those stations now in operation or under development will normally be about 33 million gallons per day.

OPPORTUNITIES FOR FURTHER GROUND-WATER DEVELOPMENT

Referring to the map of western Long Island, Sheet 1, Acc. 5530, it will be seen that the opportunities are limited for cheaply developing still more water in sparsely settled portions of the island beyond interference with existing waterworks, and at a safe distance from the salt water.

It would be possible, however, within the borough limits, to construct three additional stations and obtain, for a few years, a supply of about 7 million gallons per day.

One of the proposed stations might be located in the vicinity of Parkville; a second station in the Bay Ridge section, and a third station in Flatlands. The territory in which these stations would be constructed is either wholly or partially undeveloped, and the quality of the supply would be satisfactory for some time.

The cost of the three stations, including land and water damages, would be about $1,000,000.

These proposed stations would make the total normal yield of all the works outside of the Ridgewood system, including the existing stations, those under construction and others that might be built, 40 million gallons per day. This yield would, however, be reduced, in periods of low rainfall, to not over 32 million gallons per day.

If additional sources outside of western Long Island should not become available, it would be possible to construct temporary driven-well plants in central Nassau county, near the Main line of the Long Island railroad that would draw upon the stored rainfall in the deep sands and gravels there. A supply of 25 million gallons per day could probably be obtained in this way for several years, which might be enough to relieve the City from the danger of water famine until water from other and permanent sources could be secured.

These waters are, however, at some distance from the

City and from the present conduit lines, their development would be expensive, and the operation of such works would eventually decrease the yield of the Ridgewood system in southern Nassau county. Such a project should only be considered when other means to secure an additional water-supply have failed.

ORIGIN OF LONG ISLAND GROUND-WATERS

The success of the proposed stations in western Long Island in securing an emergency supply for Brooklyn borough should not encourage The City to believe that an unlimited supply of water may be obtained from this part of the island by increasing the number of pumping-stations, nor should the many theories suggested to explain the presence of water in the deep gravels be allowed to conceal the true origin of the underground waters of Long Island.

No more water can be drawn from the sands and gravels of Long Island than results from the rainfall on its surface. If any further proof of the origin of these underground waters on Long Island is needed than that provided by the known direction of ground-water movement shown by the slope of the surface of the water-table, it may be found in a cross-section of Long Island and the Connecticut shore.

The hard, impervious gneiss, and the igneous rocks that outcrop on the Connecticut shore and the impervious clays that cover them on the mainland and in the sound, cannot possibly carry any water to Long Island. The porous strata do not reach the Connecticut shore, and should any disturbance in the present equilibrium of the fresh and salt water occur on the north shore of Long Island, and any water come from the north, it will not be fresh ground-water but the salt water of Long Island sound. The rock formations of Manhattan island and of the New Jersey shore just as surely cut off any flow of fresh water to Long Island from the west.

The fallacy of a Connecticut or mainland origin for Long Island ground-waters has been shown by all competent geologists who have considered this question; notably by Professor W. O. Crosby of the Massachusetts Institute of Technology, Boston, and by Mr. A. C. Veatch of the U. S. Geological Survey.

RELATION OF CONSUMPTION TO SUPPLY OF BROOKLYN BOROUGH

Total Amount of Supply

The total present and prospective supply of the Borough of Brooklyn from available sources in western Long Island, is summarized in the following table:

Source	Safe Yield in Million Gallons Per Day During Years of Normal Rainfall	Probable Yield in Million Gallons Per Day During Years of Deficient Rainfall
Present works of Ridgewood system....	117	105
Other works now supplying Brooklyn borough....	18	15
Total present supply....	**135**	**120**
Additional works in Ridgewood system now under construction....	10	8
Other works now being constructed for the supply of Brooklyn borough....	15	12
Total supply that should be available during the year 1908....	**160**	**140**
Further supply from the Ridgewood system that might be secured from eight additional driven-well stations, and the completion of well systems at Wantagh, Massapequa and Springfield....	28	25
Additional supply that might be obtained from three new stations in Brooklyn borough....	7	5
Total supply for Brooklyn borough that may be made available....	**195**	**170**

The low rainfall yield in this table represents the probable delivery of the works during the next few years should these years be dry. The high rainfall of the past few years has filled the ground-water reservoirs and this storage will be drawn upon for several years to come.

Consumption

The present population of Brooklyn borough is estimated at 1,470,000, and the average supply from all sources in 1907 was 145 million gallons per day, of which the Ridgewood system furnished 124 million gallons per day and other sources in the borough limits 21 million gallons per day.

The per capita consumption of 98.6 gallons per day is low compared with that of the Boroughs of Manhattan and The Bronx, and is due largely to residential character of most

of the borough, to the borough having been insufficiently supplied with water for some years, and to the reduced pressure that has been maintained in the mains of the distribution system for much of the time since the shortage of water in the summer of 1905. The experience of the past offers little hope of any substantial reduction in the consumption below this figure.

Relation of Consumption and Supply

The relation between the estimated yield of the Brooklyn works under conditions of normal rainfall and the consumption since a public water-supply was installed is shown graphically on Sheet 3, Acc. L 678. It should be noted that under these conditions the safe yield as it is termed in this report has generally been less than the consumption since 1870, and that only an ample and favorable rainfall distribution has saved the borough from longer periods of water shortage than have occurred.

Since the year 1902, the consumption of the borough has been greater than the safe supply that the works would have yielded had the average rainfall of these years been normal. The present works could not have met the consumption during the past year had not the rainfall in western Long Island been considerably above the normal.

Even with the additional stations now under construction in the Ridgewood system and in the Boroughs of Brooklyn and Queens, there will hardly be enough water to supply the increasing consumption after the year 1909, if a normal rainfall occurs for the next two years, and probably not enough water to meet the present consumption of the borough if a period of low rainfall ensues, assuming, as we must, that the present rate of increase in consumption continues. The precipitation has been at or above the normal since 1896, with the exception of the year 1905, and it is not unreasonable to expect now a period of low rainfall.

The total supply of 195 million gallons per day from a complete development of all readily available sources in western Long Island will not probably be sufficient to meet the present increase in consumption after 1913. Should a period of low rainfall set in, the total safe supply would very likely be reduced to 170 million gallons per day, which would hardly supply Brooklyn borough through the year 1910.

URGENCY OF RELIEF FOR BROOKLYN BOROUGH

It is evident that if the present rate of increase in consumption continues an additional supply of water from new sources outside of western Long Island should be made available for the Borough of Brooklyn in 1912, and that some water may be required from new sources by 1910 should a period of low rainfall occur. No immediate relief can be obtained from the Catskill Mountain sources, for it will be impossible to complete the works from Ulster county to New York City, including the proposed pressure tunnel under the East river, and deliver water from the north to Brooklyn borough before 1916, and perhaps not even before 1918. The only sources of supply that can be made available within the next five years, to provide a large supply of water to Brooklyn borough, are the ground-waters of Suffolk county, and steps should be taken at once to develop these sources and bring a large supply to the City.

The works necessary to collect and transport these waters to the City cannot, however, be completed for several years. In the meantime, the present sources in western Long Island should be immediately developed to their full capacity to prevent a serious shortage of water in Brooklyn borough.

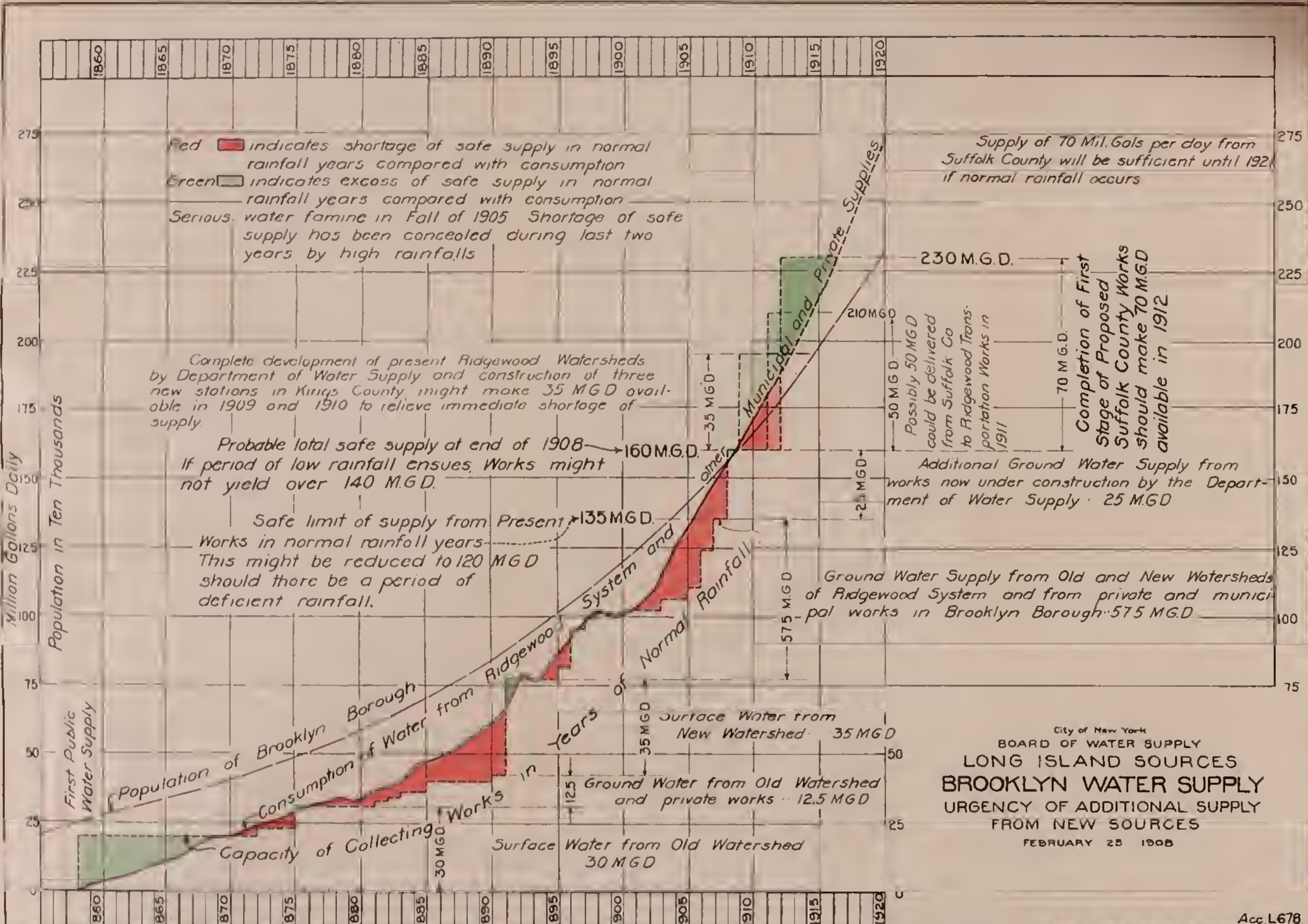
SUPPLY FROM SUFFOLK COUNTY GROUND-WATER SOURCES

Suffolk county occupies the central and easterly portion of Long Island and makes up about two-thirds of the entire area of the island. Its westerly boundary is only 30 miles from City Hall and but 16 miles from the limits of New York City.

The broad plains of Suffolk county, with their coarse, open soils, provide one of the most remarkable opportunities known for the collection of a large water-supply. If these sources were made available, they could not only be quickly and cheaply developed to provide an emergency supply for Brooklyn borough within the time in which it will probably be required, but these sources could also be made to furnish a large permanent supply of excellent water for Brooklyn, as well as other boroughs of New York City.

By skillful development, this Suffolk County supply could be appropriated from the large volumes of water now running

SHEET 3



City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
URGENCY OF ADDITIONAL SUPPLY FROM NEW SOURCES
FEBRUARY 25 1908

Acc. L678

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to waste there, without material injury to Suffolk County residents and without interfering with the growth of the county.

SOURCES IN SUFFOLK COUNTY TO BE DEVELOPED FOR NEW YORK CITY

The Suffolk County sources that would yield by far the best supply of water, and of which the development would cause the least disturbance to Suffolk County residents, are the ground-waters found in the deep sands and gravels of which the soils and substrata of Long Island are made up.

Origin of Suffolk County Ground-Waters

Like the ground-waters of western Long Island, the Suffolk County waters have their origin in the rains and snows that fall upon the surface of the island. A large percentage of this precipitation sinks quickly through the loose, porous soils, into the deep strata of coarse sand and gravel, beyond the reach of vegetation and surface evaporation. The ground-waters thus collected in the deep porous strata move very slowly toward either the northerly or southerly shore of Long Island and finally escape into the sea.

The deep wells driven during the present investigations confirm previous conclusions that these Long Island ground-water sources are fed only by the rains and snows that fall upon the surface of the island, and are not supplied, as popularly supposed, by waters from the Connecticut shore.

Quality of Ground-Waters

The waters from the Suffolk County sources would, on the whole, be better than the ground-waters of the Ridgewood system because of the more favorable location proposed for the collecting works and the smaller population on the proposed Suffolk county watershed.

The normal ground-waters in Suffolk county that are gathered outside of the villages, and at some distance from habitation, are remarkably soft, and all the ground-waters are naturally clear, colorless, and free from any pollution or infection, because of the perfect filtration of the rain-water that takes place in passing through the surface soils, and the suffocation and starvation of organic life that occur during the

months and years in which these waters remain in the earth. Altogether, these ground-waters are wonderfully pure, and in appearance, taste and temperature, are most attractive for domestic or industrial use.

Ground-Waters of Southern Suffolk County

The most favorable of the ground-water sources are the yellow water bearing strata forming the broad plains of southern Suffolk county. Large volumes of water could be made available from these sources, and their nearness to New York City, and the surface topography of the south shore, would permit both a rapid and an economical development.

It is proposed to appropriate for New York City all the deep ground-waters that are not needed for local uses in southern Suffolk county, from the Nassau County line to Shinnecock bay.

The yellow gravels in southern Suffolk county are generally deeper and more favorable for the collection of a large water-supply than the corresponding strata in Nassau county. The gray, cretaceous gravels below the gray and black clays, from which considerable water is drawn in the Ridgewood works of the Brooklyn system, are altogether absent in Suffolk county, or, if they do exist, occur at such depths as to prohibit the development of any considerable supply from them.

The north shore of Suffolk county is much less favorable than the southerly portion of the island as a gathering ground for a large water-supply. The surface soils and substrata of the glacial moraines are, in general, finer, more compact and therefore more impervious; and the much greater depth to the ground-waters, the smaller catchment area and the more irregular topography of the surface would make an extensive development of the ground-waters there more difficult and expensive.

Ground-Waters of the Peconic Valley

A complete development of the available Suffolk County ground-water sources should, however, include the surplus ground-waters in the coarse sands and gravels of the Peconic valley. This valley lies at the head of the Great Peconic bay, between the two morainal hills, into which the main ridge, or "back bone" of the island, divides in eastern Nassau county.

The amount of water to be obtained from these Peconic Valley sources would not be large, even without any reservations for local uses, but the collection of the water should not be expensive, and it could readily be delivered to the main south shore works.

AMOUNT OF WATER TO BE APPROPRIATED FROM SUFFOLK COUNTY SOURCES

Area of Ground-Water Catchment

The total catchment area of these Suffolk County sources amounts to about 332 square miles. Of this, 294 square miles represent the drainage area of the south shore ground-water sources and 38 square miles the catchment area of those in the Peconic valley.

Total Yield of These Sources

The average annual rainfall on the Suffolk County watersheds is estimated as 45 inches. It is safe to estimate that 37 per cent. of this rainfall, or 16.7 inches depth, which is equivalent to an average daily yield of 800,000 gallons per square mile, can be secured from these Suffolk County catchment areas if an adequate amount of ground-water storage is made available in years of extremely low rainfall. This estimate is based upon the amount of water now being obtained from the sources of the Ridgewood system of the Brooklyn works in western Long Island, and upon the yield of other similar drainage areas.

The normal yield of the ground-water catchment area of the old watershed of the Ridgewood system is about 900,000 gallons per day per square mile, or 43 per cent. of the average rainfall of 44 inches in western Long Island. It appears that both the old and the new watersheds, if fully developed, will yield nearly 1,000,000 gallons per day per square mile during years of normal rainfall. European watersheds of similar character, on which the rainfall is much less than on Long Island, have delivered for some years from 40 to 50 per cent. of the rainfall, and it would be reasonable to expect an equally large or even greater percentage of collection from these Long Island catchment areas because of the larger rainfall here.

On the basis of a unit yield of 800,000 gallons per day per square mile, the total average collection from the catchment

area of 332 square miles in southern Suffolk county and in the Peconic valley would be 266 million gallons per day.

Net Supply to be Appropriated for New York City

If the complete development of these deep ground-waters should, in the future, deprive the Suffolk County people of their sources of water-supply, seriously lower their ponds and streams, or in any way prove detrimental to their interests, sufficient water for all real needs should certainly be reserved to them. New York City must recognize the priority of right of the Suffolk County towns to sufficient water to satisfy all reasonable demands for domestic water-supply.

Even if it appears that the collection of the deep ground-waters might possibly interfere with local sources of supply, it would seem best that New York City should completely develop these ground-waters and reserve, if necessary, from the total yield the water required for local needs. This plan would be preferable to the alternative of setting aside portions of the catchment area for local uses.

The amount of water that need be thus reserved in Suffolk county for the supply of the local population and for the uses of the few manufacturing interests, or that might be lost in maintaining the levels on some of the south shore streams, would be a small part of the whole, and would not for many years greatly diminish the net supply that could be conveyed to New York City.

The present resident population in the watershed is about 39,000, of which it is estimated that only 17,000 are within the area that would be affected by the operation of the proposed collecting works. The larger number represents, perhaps, more nearly the population that would be supplied from the proposed works, and this number is increased for a few months of the year by the summer visitors. It seems very unlikely that 50 years hence, say in 1960, the total population to be supplied would exceed 100,000. If this entire population were provided with water, they would not probably require more than 15 to 20 million gallons per day.

With the probability of a larger unit yield from the Suffolk County watersheds than has been adopted in these estimates, there would be no difficulty for many years in appropriating for New York City a net supply of 250 million gallons per day.

METHOD OF COLLECTING GROUND-WATER

It is proposed, in general, to collect these Suffolk County ground-waters before they escape into the sea, on lines that would permit of a maximum yield of the catchment area, consistent with a reasonable security against any pollution or impairment of the quality of the supply.

On the lines of development in Suffolk county that are suggested on the general map, Sheet 4, Acc. 5602, page 26, it is proposed to acquire a right-of-way, 600 to 1000 feet in width, in order to prevent the encroachment of dwellings on the collecting works, and thoroughly protect the ground-waters from pollution. This width of right-of-way would also permit of securing pleasing landscape effects and of constructing highways lengthwise of the island leading to and from New York City. These improvements would add much to the attractiveness of the project and greatly facilitate the efficient operation of the proposed works.

Wells and Pumping System

The ground-waters could best be collected on these locations by means of a continuous line of deep wells constructed at intervals along the center of the right-of-way. It is proposed to pump the water from these wells by means of suitable deep well pumps and electric motors, each of which would be operated independently from substations at intervals of about four miles. All would be driven from a central power-station to be located at tide-water on the Great South bay.

Collecting Works in Southern Suffolk County

The location proposed for the collecting works in southern Suffolk county is, for much of its length, in the scrub oaks and pine barrens, only sparsely settled and but little farmed. The works would be everywhere north of the large villages and the scattered farms and summer residences, and at some distance from the many ponds along the south shore.

The land on this location should not be expensive, nor the consequential damages large. The collection of the ground-waters on this location would disturb only a few residents of southern Suffolk county, and would hardly affect the water-levels in many of the streams and ponds.

This location would furthermore provide an insurance of

the continued purity of the supply. There would be little danger of pollution of the ground-waters by the local population. More important still, the distance from the south shore bays to the collecting works would be sufficient, under reasonable conditions of operation, to protect the proposed works from the infiltration of sea-water which, because of its greater specific gravity, fills the deep strata at some distance from the shore. If this salt water were permitted to reach the wells of the proposed works, the mineral contents of the ground-water would be greatly increased and the supply would become extremely hard and quite undesirable for both domestic and commercial uses.

Fresh-Water Reservoirs on the Salt-Water Estuaries

To further safeguard from the sea-water the supply collected on the above location, it is proposed, on the estuaries of the larger south shore streams, to construct low earth dams and create reservoirs of fresh waters that would crowd out the sea-water in the underlying sands and gravels and minimize the danger of the salt water reaching the wells of the proposed collecting works. Reservoirs are proposed on the Connetquot river, Brown's creek, Patchogue creek, Swan river, Mud creek, Carman's river, Forge river, Terrell river, Seatuck creek, Speonk river, Beaverdam creek and Quantuck river.

These dams and reservoirs, with the proposed rollways and locks on the larger estuaries, would improve boating and navigation on these streams and greatly increase their natural beauty.

Branch Lines for Additional Storage

Even with these protecting works there would, at times, be danger from sea-water, if large volumes of ground-water storage were drawn on this south shore location during long periods of extremely low rainfall to maintain the normal yield of the catchment area. It is proposed, therefore, to construct collecting works on three branch lines, to Melville, Lake Grove and Middle Island, respectively, by which to secure additional ground-water storage from the deep water bearing strata in the center of the island.

Deep wells are proposed within a wide right-of-way as on the main south shore line. It would be possible on these

branch lines to pump large volumes of ground-water during periods of extreme drought, without danger from sea-water.

Collecting Works in the Peconic Valley

The ground-waters of the Peconic River valley could be developed by means of a line of wells along the south bank of the Peconic river from Riverhead to Calverton, on a strip of undeveloped land averaging perhaps a thousand feet in width. A transmission line would be constructed from the central power-station on the south shore, to furnish power for pumping these wells.

Utilization of Flood Flows in Surface Streams

In order to avoid the loss of the flood flows which occur in the larger surface streams of Suffolk county, it is proposed on the Carll's river, Connetquot brook, Patchogue river and Carman's river, to construct small storage reservoirs or infiltration basins above the main line of the collecting works. The existing ponds on the Peconic river would serve to impound the flood flows of that stream. By means of wells driven about the margins of these basins, the surface-waters would be drawn through the coarse sandy bottoms, and delivered completely purified to the transportation works as "artificial ground-water."

These reservoirs are planned to be in operation only at times when the flow of the streams is in excess of their normal summer discharge. They would not be used to regulate the delivery of the deep ground-waters, and the present surface ponds would be equally valueless for this purpose in the system of ground-water collecting works proposed. The ground-water storage in the deep sands and gravels could be made ample in volume to meet the fluctuations in the ground-water yield, and would be preferable to any surface storage.

Removal of Iron

The present investigations indicate that it would not at first be necessary to treat these Suffolk County waters for the removal of iron. Should the iron contents increase, and such treatment be required after some years of operation, the works necessary for the treatment of the water could readily be constructed in the sections where the amount of iron is high.

PROTECTION OF SUFFOLK COUNTY INTERESTS

One of the first steps toward the acquisition of the Suffolk County waters should be that of safeguarding local water-supplies, and providing ample protection to all Suffolk County interests.

The people of Suffolk county fear that the diversion of any of their water to New York City would interfere with the growth of the county and be detrimental to their agricultural interests and other industries. The owners of large estates and members of the clubs on the south shore believe that the appropriation of Suffolk County waters would reduce in volume the flow of their streams, lower the surface of their ponds, and thus greatly detract from the beauty and enjoyment of their property.

The ground-water works of the Ridgewood system in Nassau county were hastily constructed in times of severe water shortage in Brooklyn, and for reasons of economy were placed near existing conduit lines that had been originally located to secure only a surface-water supply. Because of the methods of collecting the ground-water adopted, and the unfortunate location of these works near the south shore towns, their operation has caused some annoyance to local residents and has given the people of Suffolk county some reason for their fears. It is believed, with the more favorable location proposed for the Suffolk County works, north of the south shore villages, and by the better methods of collection that are here suggested for the new Suffolk County system, that much of the annoyance, that has occurred in Nassau county, may be avoided.

Amount of Suffolk County Water Being Utilized

The Suffolk County waters are now being utilized only to a limited extent for the supply of the resident and transient population, for street and lawn sprinkling, boiler feed, wash water and water-power. The amount of ground-water used for domestic and commercial purposes is relatively small, and the waters of many of the surface streams at present run to waste and serve no useful purpose.

The total amount of water that is now used within the watersheds that it is proposed to develop is estimated as follows:

	Million gallons per day
Public water-supply (maximum ground-water pumpage of local water-works in summer months)....	5
Steam-power, wash water and other small commercial uses (surface and ground-waters)..........	1
Water-power (average flow of surface streams that may be utilized for power) about...............	80
Total amount of water used..............	86

Local Water-Supply

Water for domestic supply, steam-power, wash water and similar uses would need to be supplied by New York City from the proposed works, at a reasonable price, in the event of the proposed collecting works interfering with the present sources of supply. The Suffolk County towns should receive positive assurances that New York City will make good to them the ground-water of which the proposed collecting works might deprive their local works, and that in the future The City would always provide these towns with an ample supply of water, as the population increases.

Surface Streams

While any plan to appropriate the surface streams should be frankly disclaimed, it is hardly conceivable that a complete development of the deep ground-waters would not eventually result in some lowering of the surface ponds and in some decrease in the flow of the streams that are near the location of the proposed collecting works, unless the works are planned, as now proposed, to properly maintain these natural features.

Many of the small ponds and streams along the south shore are, however, so far from the proposed works that their surfaces would be maintained by the rainfall on their immediate watershed and would be but little affected by any lowering of the ground-water on the location proposed.

A small amount of water-power is developed on the larger surface streams. If the normal flow of these streams should

be decreased by the operation of the ground-water works, the power could be replaced at comparatively small expense by steam plants or perhaps by electric power from the proposed central power-station for the operation of the well system. The total hydraulic equipment now in use on the surface streams is estimated to aggregate only 220 horse-power.

Maintenance of Surface Ponds

The objections of the owners of the streams and ponds which form such an attractive feature of southern Suffolk county should not be difficult to meet, if the owners are approached in a spirit of fairness and good will. These people do not care to sell their ponds and streams, or the lands adjacent to them, nor do they wish to have the surfaces of their ponds lowered to an extent that would expose unsightly banks.

The large volumes of water now running to waste over the spillways of many of these ponds do not, however, appear essential either to the attractiveness of these ponds or to the wholesomeness of their waters. A reduced flow would answer in most cases equally as well, and little complaint should arise as long as the ponds remained full.

If, however, the operation of the proposed works lowered the water in any ponds below their spillways, sufficient water should be delivered to these ponds from the proposed collecting works, to maintain the surface of the ponds at or very near their spillway level, as the Brooklyn department is now doing at Massapequa lake, a pond just below their collecting works.

But little of the water thus diverted to these ponds would be really lost as long as the ponds were kept at the level of or slightly below the crest of the spillways, because most of the water would be drawn back to the collecting works through the bottoms of the ponds and the pore spaces of the earth. A complete and continuous circulation through the ponds would thus be created, and the wholesomeness of their waters and their original volume and appearance would be preserved. If it were not feasible to divert water from the aqueduct, a continuous circulation could be maintained by means of small independent pumping units located a short distance above the ponds.

The only cost of keeping up these pond levels would be that of pumping from the ground the water required for the circulation, and doubtless the expenditure would be well worth while, aside from the value of maintaining the appearance of the ponds, in that a full pond would protect the collecting works against the entrance of sea-water from the south shore bays.

If it should happen that the pumping at the proposed works lowered the water in any ponds that were so near the south shore, or so far from the collecting works that little or none of the water delivered from the collecting works would return, it would, perhaps, be even more satisfactory to lower the spillways and dredge out the beds of these ponds to remove any shallows uncovered in the lowering of the water-level. The original depths and areas of water surface with attractive slopes of clean sand and gravel could be secured by this means at no great expense. The dredging of the loose sands and gravels from the beds of these ponds could be done very cheaply, and the adjacent swamps and low salt marshes could be greatly improved by delivering the dredged material to them and raising their surfaces.

Agricultural Interests

The isolated householders and the owners of the few farms that are located north of the south shore villages, in the vicinity of the proposed collecting works, would doubtless expect compensation from The City for any material lowering of the water in their wells and for any damage to their crops that might be caused by the operation of the proposed works, and The City would expect to pay all reasonable claims of this kind. Such claims would, however, be minimized by the purchase of a right-of-way 1000 feet in width, since the depression of the surface of the ground-water outside of this right-of-way would be comparatively small. The number of these claims would, at any rate, be few on the proposed location of the collecting works, for much of the line is in the scrub oak and pine barrens, far from habitations.

Investigations have shown that when the ground-water surface is over five feet below the surface of these coarse Suffolk County soils, no moisture reaches the surface or the roots of vegetation through capillary action.

Only 15,000 acres or 7 per cent. of the entire surface of the proposed Suffolk County watersheds, of 332 square miles, or 212,000 acres, is less than five feet above the ground-water, so that the crops, the trees and other vegetation on the remaining 93 per cent. is now watered entirely by the rains that slowly percolate through the soils to the deep water bearing strata.

The adequacy of this source of moisture for growing crops has been demonstrated by the Long Island experiment station at Medford, where the ground-water is 40 feet below the surface of the ground. Excellent crops of all kinds were grown there last year, where nothing but scrub oak existed before.

Of the 7 per cent. of the entire watershed surface, which is perhaps near enough to the ground-water surface to derive some moisture from it, 10,100 acres, or hardly 5 per cent., is near enough to the proposed collecting works to be effected by their operation, and 4,000 acres or 40 per cent. of this is water surface or meadow and swamp lands that would be improved by the lowering of the water-table below the top-soils. Damage could not possibly occur on more than 6,100 acres, or 2.9 per cent. of the catchment area, and of this only 850 acres, or 0.4 per cent. of the whole watershed is now under cultivation.

Other Suffolk County Industries

Many of the objections raised in Suffolk county by the opposition to the appropriation of the surplus waters of Suffolk county are not well founded, and it should not be difficult to show this to those who present them. Much has been said, for example, about the danger to the oyster industry, of diverting from the south shore bays any portion of the fresh water that now enters.

It can be shown that the fresh water that it is proposed to appropriate for New York City could be diverted from the Great South bay without much harm to the oyster industry. A small portion of the beds might be slightly injured by the increase of the salinity of the water, but this injury would be offset by the increase in salinity of the water in other portions of the bay, where the water is now too fresh for the proper growth of the oyster. The slight increase in salinity in the Great South bay would not affect the food supply of the oyster,

change the character of the bottom of the bay, nor materially increase the growth of the starfish and other enemies of the oyster. The conditions for the culture of oysters in Shinnecock bay, after the proposed diversion of the ground-waters, would be more favorable than at present, because the waters of this bay are somewhat too fresh for the oyster, even with the salt water that enters through the canal from Peconic bay.

Advantages to Suffolk County in the Proposed Works

The residents in Suffolk county should not overlook the many advantages to be gained by them in the construction of the proposed works. While a few would doubtless be inconvenienced during the period of construction, the building of new highways parallel with the south shore would make large areas of Suffolk county more accessible, and the improvements proposed on the right-of-way that The City purchases would add much to the attractiveness of the country through which the works would be constructed.

The money that would be expended here by New York City in land purchases, and the amounts that would be disbursed for labor and materials, would mean much to the material prosperity of the county for many years. The water-supply that would be furnished the residents of Suffolk county from the proposed aqueducts would be ample in volume, and of a better quality than that now supplied from some of the pumping-stations within the village limits.

TRANSPORTATION OF SUPPLY TO NEW YORK CITY

Masonry Cut-and-Cover Aqueducts

It is proposed that the ground-water collected in Suffolk county be conveyed to New York City in cut-and-cover aqueducts of concrete masonry similar to that being constructed on the Catskill works. For a large permanent supply that is to be transported some distance, this character of construction is cheaper, both in first cost and in operation, than steel-pipe lines, and is much more durable.

The waters in southern Suffolk county could be conveyed entirely by gravity in this type of masonry aqueduct, from the easterly limit of the collecting works to a pumping-station in Brooklyn, where the waters would be raised to a distributing reservoir or delivered directly to the City mains.

The Peconic Valley waters could be similarly conveyed in a cut-and-cover aqueduct to a pumping-station near Riverhead. From this point, it is proposed to pump these waters through cast-iron pipes over the divide separating the Peconic valley from the southerly slope of the island, to the main south shore aqueduct at Westhampton, through which they would flow by gravity to Brooklyn borough, mingled with the waters of southern Suffolk county.

The general location of these Suffolk County aqueducts are shown on Sheet 4, Acc. 5602, page 26.

Capacity of Proposed Aqueducts

It is proposed to make the nominal capacity of the main aqueduct through Nassau county, Queens borough and Brooklyn borough, by which to transport the proposed supply from Suffolk county, 250 million gallons per day.

The capacity of this aqueduct from Smith's pond to Brooklyn may be readily made 300 million gallons per day by increasing the slope between these points. This additional capacity would permit inspection and repairs on the old brick conduit of the Ridgewood system, which now cannot be put out of service for this purpose without imperilling the supply of Brooklyn borough.

The main aqueduct in Suffolk county need not be constructed of the full capacity beyond Great River, which is 15 miles from Nassau county. It is planned to provide for the aqueduct in any section a carrying capacity proportional to the tributary catchment area, and to make the aqueduct sufficiently large to permit the transportation of the maximum pumpage of all portions of the collecting works. The size of the aqueduct would be successively reduced by amounts corresponding to capacities of 25 to 50 million gallons daily, until at the junction of the Peconic aqueduct, east of Westhampton, its capacity would be only 100 million gallons per day. The last few miles of the main line need not have a daily capacity in excess of 25 million gallons.

The Peconic Valley aqueduct, the force main and aqueduct from Riverhead to Westhampton, and the three branch conduits to the center of the island, are each planned to have a nominal capacity of 50 million gallons per day.

CONSTRUCTION OF SUFFOLK COUNTY WORKS

With the introduction of the Catskill supply within the next few years, the needs of New York City would not require immediately the entire supply of 250 million gallons per day from the Suffolk County sources. The small margin between the consumption and supply in Brooklyn, the exhaustion of available sources in western Long Island and the impossibility of securing immediate relief from the Catskill sources, make it imperative, however, to complete at an early date such portions of the proposed Suffolk County works as would supply sufficient water to place this portion of the City beyond any danger of a water famine.

First Works to be Built

The first stage of construction of the Suffolk County works would naturally include the main aqueduct of full size from Ridgewood in Brooklyn borough to Great River, about 15 miles from the Nassau-Suffolk County line, the collecting works of this first section in Suffolk county and as much of the central power-station, transmission works and the pumping-station in Brooklyn as would be necessary for this development.

The south shore of Long Island presents no obstacles to the most rapid construction of the proposed works. Under favorable circumstances, the great part of this first section of the Suffolk County works might be completed by the year 1912, and would provide a normal supply of 70 million gallons per day. This amount of water would probably be sufficient for both Brooklyn and Queens boroughs for six or eight years after its introduction without any water from the north.

The next stage in the construction of the aqueduct lines and collecting works in Suffolk county would be the section of 15 miles from Great River to South Haven, which, with the first, would yield 150 million gallons per day. Following this, the remainder of the south shore works, about 19 miles in length, would be built to a point near Quogue, when about 220 million gallons per day could be obtained from the entire works. The Peconic Valley collecting works, about four miles in length, and the force mains and aqueduct from Riverhead to the south shore, a distance of about six miles, would next be constructed to secure the entire supply of 250 million gallons per day, after which the three branch lines, aggregating about 24 miles, would be built to make available the storage neces-

sary to maintain this supply during periods of deficient rainfall.

Emergency Supply in 1910

An emergency supply from Suffolk county nearly as great as that from the first stage of construction could, perhaps, be delivered to Brooklyn borough by 1910 if the Department of Water Supply begins at once the extension of the 72-inch steel-pipe line from Clear stream to Massapequa and constructs the two pumping-stations at Massapequa and Wantagh, as now proposed.

The 72-inch pipe-line is designed to carry 50 million gallons per day on a gradient of 2.2 feet per mile when pumping from Massapequa and Wantagh against the full distribution pressure in Brooklyn borough. At times of low rainfall, when the Suffolk County supply would be most needed, there would be an excess capacity in this pipe-line of 40 million gallons per day. By increasing the gradient slightly, doubtless 50 million gallons of Suffolk County water could be delivered through this line against the full City pressure. The excess capacity that would be provided at the Massapequa station should be ample to pump this amount of water.

The first Suffolk County works should, therefore, be so planned that the construction necessary to deliver this amount of water could be completed, if possible, by 1910. The development of this emergency supply would require only a portion of the works included in the first stage of construction and would postpone a large expenditure on Long Island until a much larger supply was required.

The first 10 miles of the Suffolk County collecting works and aqueduct, and about two miles of the main aqueduct from the Suffolk County line to Massapequa supply pond would be built first, and a steel or concrete pipe constructed on the City property from the end of this aqueduct along the east side of Massapequa pond to the new pumping-station proposed by the Department of Water Supply. The Suffolk County aqueduct would be high enough to deliver the water by gravity to this pumping-station.

To avoid the immediate purchase of the right-of-way beyond the first 10 miles of the collecting works and the construction of the proposed central power-station at Patchogue, a temporary power-house could be built on the right-of-way at

the Hempstead branch of the Long Island railroad near Babylon, to furnish power for the operation of the well system.

Only a small part of these preliminary works need be abandoned on the completion of the main aqueduct to the proposed pumping-station in Brooklyn. Much of the equipment of the temporary power-house could become a part of the permanent central power-station, and the pipe-line to the proposed Massapequa pumping-station could well serve to deliver a portion of the Nassau County supply into the main Suffolk County aqueduct, when it should be necessary in the future to make repairs on the Ridgewood conduits.

COST OF SUFFOLK COUNTY SUPPLY

The estimated cost of the complete works by which a total supply of 250 million gallons per day would be available is $47,173,000.

The cost of this Suffolk County water for each million gallons delivered into the distribution system of Brooklyn borough would be about $44.18. This includes ample allowances for operating expenses and depreciation, for the payment of interest at four per cent. on 50-year bonds, and for a sinking fund drawing 3 per cent. interest to pay off bonds when they mature. No allowance is made, however, for interest payments during the period of construction.

Comparison with Other Estimates and Other Works

In the report on the future extensions of Water Supply of Brooklyn, Mr. I. M. de Varona, in 1896 (see Tables 46 and 47 of his report), it was estimated that the cost of a supply from Suffolk county of 100 million gallons per day would be $39.03 per million gallons. Mr. de Varona's plan was to develop about the same territory as here suggested at Stage 2.

It was proposed, however, to use steel-pipe lines instead of masonry aqueducts and to make a much less extensive development of the ground-waters than now estimated upon. (See pages 23 and 24 of the Brooklyn Report.)

Mr. de Varona's estimate of 1896 of $39.03 per million gallons for the Suffolk County water, should probably be increased now by $2 or $3 and perhaps more, to make it comparable with the present estimates, because of the present 8-hour day, the increase in wages, the higher rate of interest, and the larger allowance for depreciation and taxes that has

been made. (See Mr. John R. Freeman's report on New York's Water Supply, Appendix 15, page 532.)

The present cost of the supply from the Ridgewood system, delivered at the Ridgewood pumping-station into the distribution system, is estimated at $45.69 per million gallons, but this includes the interest and sinking fund charges on some bonds that have been retired. The actual cost to-day does not probably exceed $36 per million gallons.

The estimated cost of the Catskill supply delivered in Brooklyn borough, including fixed charges and operating expenses, is about $45 per million gallons, which is practically the same as that of the Suffolk County water. When, however, the works are paid for 50 years hence and the bonds retired by the operation of the sinking fund, the water from the Catskill works would be cheaper to the next generation because of the larger operating expenses of the Long Island works.

Summary of Cost of Suffolk County Works

The total expenditure on the proposed Suffolk County works at each stage of construction, the probable safe yields of the works, and the cost of the water per million gallons, are shown below:

Stage of Construction	Description	Probable Yield of Works at this Stage Million Gallons Daily	Estimated Total Cost of Construction	Cost of Water per Million Gallons Delivered into City Mains
Preliminary..	Ten miles of collecting works and aqueduct to Massapequa...........	50	$7,153,000	$37.78
1...........	Complete works, Brooklyn to Great River.......	70	21,742,000	62.21
2...........	Additional, Great River to South Haven..........	150	30,262,000	44.53
3...........	Additional, South Haven to Quogue...............	220	38,355,000	40.12
4...........	Peconic Valley works, Westhampton to Riverhead and Calverton.........	250	40,179,000	39.24
5...........	Three branch lines........	250	47,173,000	44.18

The cost of each million gallons of water delivered to the City on the completion of the first stage of construction is seen to be $62.21, including allowances for interest and sinking fund. This is much greater than the final unit cost of the water when the entire works are finished, because this first cost includes the charges on the large masonry aqueduct to Brooklyn borough and on portions of the collecting works and pumping-station, which should be built, at first, of full

capacity for the complete development. The branch lines add materially to the cost of the supply, but they are essential to the most complete development of the flood waters of the larger surface streams as well as an insurance against the reduction of the yield during long periods of low rainfall. They may, however, be deferred for several years after the completion of Stage 4, until the demand for Suffolk County water approaches the average yield of the watershed, and the water-table has been depressed near the south shore through the operation of the collecting works.

Annual Expenditures

The Suffolk County works would not require a large expenditure for several years. Of the cost of the preliminary stage of development, the entire sum of $7,200,000 would not probably be needed until some time after the first 10 miles of the collecting works were in operation, because only at that time would there be any claims for water damages, and much of the work of improvement of the right-of-way could not be completed until the works were built. The entire cost of the works, comprising the first stage of construction would be likewise deferred.

The sums that might be required each year until the first stage of construction was completed and water was being delivered through the large masonry aqueduct to Brooklyn, are estimated as follows:

Preliminary, land, etc.	$1,000,000
First year of construction	2,500,000
Second year of construction	*3,700,000
Total preliminary stage	7,200,000
Third year of work	3,500,000
Fourth year of work	6,000,000
Fifth year of work	5,000,000
Additional first stage	$14,500,000
Total on completion of first stage of construction	$21,700,000

* Completion of preliminary stage

If it were decided, on the completion of the preliminary works, to defer the first stage of construction, which includes the large masonry aqueduct to Brooklyn until perhaps 100 or 150 million gallons per day were needed from Suffolk county, the final expenditure in the third year would be only the cost of the preliminary works, $7,153,000. The above figures are based upon a more rapid rate of progress than is ordinarily attained on public work of this magnitude; but the work is of the easiest description and the needs of Brooklyn are so urgent that the works should, if possible, be finished within the time here estimated.

PROVISIONS FOR COMPLETE DEVELOPMENT OF SUFFOLK COUNTY SOURCES

The diagram of consumption, Sheet 3, Acc. L 678, brings out clearly the fact that the water-supply of Brooklyn borough has been inadequate for much of the time since a public water-supply was introduced there in 1859. The present works are, for the most part, of a temporary character, and were built piecemeal, year by year, to meet the urgent needs for additional water-supply.

It would seem but fair to Brooklyn borough, when further construction is planned on Long Island, to lay out the new works of full capacity for the complete development of Suffolk County sources, in order that there may be, in the future, no chance for the recurrence of another shortage of water. It would be to the advantage of the entire City to have another large independent supply in addition to those from the Ridgewood, Croton and Catskill sources.

The ground-waters of the Suffolk County sources are of excellent quality. The watersheds from which this water may be obtained are too near the City, and the available supply is of too great a volume to be neglected by New York City in providing for its future population.

At the present rate of increase in the consumption of water in New York City, the entire yield of all the sources of water-supply, including the development of 500 million gallons per day from the Catskill sources, will be needed within about 20 years. The Suffolk County sources would probably furnish the cheapest supply at the expiration of that time, and if not developed now, would be required then. Since a portion of the supply from these sources is now necessary for the relief

of Brooklyn, the future may be best provided for by building the main aqueduct of full capacity to ultimately carry the entire yield of the Suffolk County sources.

Development of 150 Million Gallons Per Day

A less complete development than that proposed might be made of the ground-waters from Nassau county to South Haven, which are included in the first two stages of the works for full development. With the Melville and Connetquot branches, this project would provide a supply of 150 million gallons per day at a cost of $30,565,000.

Except in the small size of the main aqueduct, these works would be identical with those for the complete development of 250 million gallons per day. These works could be built in the same time as the larger development and could be similarly developed to furnish an emergency supply of equal amount to Brooklyn borough.

Temporary Developments

If it were deemed inadvisable to secure at this time a permanent supply from Suffolk County sources, a temporary development of 50 million gallons per day could be made at a much reduced cost. This development would correspond to the preliminary stage of the permanent works, and would include a masonry aqueduct with a nominal capacity of 50 million gallons per day, from the proposed Massapequa pumping-station to Babylon, about 10 miles from the Nassau County line. This temporary supply would be delivered to the City, as before, through the proposed extension of the 72-inch steel-pipe line.

For these temporary works, eight driven-well plants of the same character as those of the present Brooklyn plants would be built about a mile apart, along the line proposed for the permanent works. The full width of right-of-way for the continuous development would only be purchased where the wells were driven, and the highways and other public improvements previously suggested would be omitted.

The cost of these temporary works would be about $2,991,000.

This does not include any provision for securing storage from the center of the island, as estimated upon in the permanent works. As the highways and other improvements are

also omitted, the total cost of the works and the annual charges are not exactly comparable with the other estimates.

It is assumed that these temporary works would have a life of 10 years, at which time there would be an ample supply of water from the Catskill sources to meet the needs of the Long Island boroughs of New York City, and that Suffolk County waters would no longer be needed. The equipment, much of which would have greatly depreciated at the end of 10 years, would then be disposed of.

By increasing the pumping capacity at the Massapequa station and providing additional pumps at or near Ridgewood to pump against the distribution pressure, the proposed 72-inch pipe-line could be made to deliver to the City from Massapequa 100 million gallons per day in excess of the amount of water from the Ridgewood system that would be pumped through this pipe during periods of low rainfall.

A temporary development of 100 million gallons per day similar to the first temporary project has, therefore, been estimated upon. This supply could be obtained from the first 20 miles of the Suffolk County line from Nassau county to Sayville by temporary driven-well stations as before. The cost of the works, including additional pumps at Massapequa and Ridgewood would be about $6,737,000.

Comparison of Annual Charges and Cost of Water

The fixed charges and operating expenses of the temporary works and also the permanent project for 150 million gallons per day are compared in Table 2 with those for the complete development of 250 million gallons per day. The fixed charges include interest payments at four per cent. on 50-year bonds, and an allowance of 0.887 per cent. a year for a sinking fund paying three per cent. The operating expenses include liberal amounts for taxes, operation, maintenance and depreciation.

It is evident that between the two projects for permanent development of the Suffolk County sources, the economy of the second one for 150 million gallons per day does not offer a sufficient saving, either in the preliminary or the final stage of construction, to offset the advantages of the larger aqueduct in permitting a rapid extension of the works in the future to secure the entire Suffolk County supply.

Stage 2 of each of the Projects 1 and 2, may best be compared.

TABLE 2

COMPARISON OF COSTS OF AND ANNUAL CHARGES ON PROJECTS FOR THE COLLECTION OF SUFFOLK COUNTY WATERS AND THEIR TRANSPORTATION TO NEW YORK CITY

February 25, 1908.
Revised May 16, 1908.

PROJECT NO.	STAGE OF CON-STRUCTION	AVERAGE SUPPLY M.G.D.	ESTIMATED COST			ANNUAL CHARGES ON THESE WORKS							COST PER MILLION GALLONS
						FIXED & OPERATING EXPENSES		COLLECTING AND TRANSPORTATION					
			COLLECTION	TRANSPORTATION	TOTAL COST	FIXED CHARGES *	OPERATING EXPENSES TAXES AND DEPRECIATION	COST OF COLLECTING	COST OF COLLECTING MIL. GAL.	COST OF TRANSPORTATION	COST OF TRANSPORTATION MIL. GAL.	TOTAL	
1	Preliminary	50	$ 3 963 000	$ 3 190 000	$ 7 153 000	$ 349 500	$ 339 800	$ 394 800	$ 21.63	$ 294 500	$ 16.14	$ 689 300	$ 37.77
Permanent Supply	1	70	6 774 000	14 968 000	21 742 000	1 062 500	526 500	608 600	23.82	980 400	38.37	1 589 000	62.19
of 250 M.G.D.	2	150	10 929 000	19 333 000	30 262 000	1 478 900	958 100	1 016 500	18.57	1 420 500	25.94	2 437 000	44.51
	3	220	15 598 000	22 757 000	38 355 000	1 874 400	1 346 500	1 478 100	18.41	1 742 800	21.70	3 220 900	40.11
	4	250	16 870 000	23 609 000	40 479 000	1 978 200	1 601 700	1 668 200	18.28	1 911 700	20.95	3 579 900	39.23
	5	250	22 021 000	25 152 000	47 173 000	2 305 300	1 713 300	2 061 400	22.59	1 967 200	21.56	4 028 600	44.15
2	Preliminary	50	3 963 000	2 677 000	6 640 000	324 400	339 300	394 800	21.63	268 900	14.74	663 700	36.37
Permanent Supply	1	70	6 556 000	12 677 000	19 233 000	939 900	504 300	591 900	23.17	852 300	33.36	1 444 200	56.53
of 150 M.G.D.	2	150	10 723 000	15 906 000	26 629 000	1 300 800	884 400	1 000 200	18.27	1185 500	21.65	2185 600	39.92
	3	150	13 758 000	16 807 000	30 565 000	1 493 700	1 026 000	1 241 900	22.68	1 277 800	23.34	2 519 700	46.02
3 Temporary Supply	1	50 for 10 years	1 675 000	1 316 000	2 991 000	325 200	309 400	342 300	18.76	292 300	16.01	634 600	34.77
4 Temporary Supply	1	100 for 10 years	3 040 000	3 697 000	6 737 000	775 700	870 900	664 800	18.22	981 800	26.90	1 646 600	45.12

* *Fixed charges include interest at 4% on 50 year bonds and allowance of 0.887% annually for sinking fund, drawing 3% interest for 50 years.*

B.W.S.389.

Each comprises complete works to South Haven for the development of 150 million gallons daily without branches. The difference in cost of $3,645,000 represents the difference of 100 million gallons daily in the capacity of the aqueduct from Brooklyn to South Haven, a distance of 54 miles. The difference in fixed charges is seen to be $178,100 per annum. This sum, in 20 years, if compounded at four per cent., would amount to $5,520,000, which would not build another aqueduct of 100 million gallons daily capacity 54 miles in length out to South Haven.

The high cost of operation of the works estimated in Project 4 for a temporary development of 100 million gallons per day does not make this attractive. The choice evidently lies between Project 1, the complete development of the Suffolk County sources to 250 million gallons per day, and Project 3, the temporary development of 50 million gallons per day, in which the entire equipment is charged off in 10 years.

If the Suffolk County waters were to serve only as an emergency supply to relieve Brooklyn borough until the Catskill supply could be introduced, the project for a temporary supply should be adopted. If an interval of 10 or 15 years should elapse after the Catskill supply is introduced, when the Suffolk County waters would not be required, it would be cheaper to build the temporary works and abandon them at the end of 10 years, rather than pay the fixed charges, taxes and depreciation on permanent works that were not being operated.

On the other hand, it is seen that the annual charges on the preliminary stage of Project 1 would be but little greater than those on the temporary development of 50 million gallons per day, with the assumed life of 10 years. If a supply of 50 million gallons per day from Suffolk county were to be required continuously for, say, 20 years, until the entire supply from Suffolk county were required, it would be preferable to construct the permanent works with the aqueduct of full capacity for a complete development of Suffolk County waters.

With the prospect of abandoning some of the present ground-water stations in western Long Island, and the rapid increase in the population of both Brooklyn and Queens boroughs in consequence of the improved transit facilities that will be soon provided, it is believed that a large part of the 50 million gallons per day from Suffolk county will always

be required. It would even be good policy to at once construct the entire masonry aqueduct to Brooklyn borough, as provided in Project 1, if the money were available, in order that the next extension of the works could be made promptly when more water is required.

DETAILS OF INVESTIGATIONS

The results of the studies that have been made of the Long Island sources and the details of the estimates of cost, on which are based the foregoing statements and conclusions, are given in the 17 appendices following this report. All elevations given in plans, profiles and diagrams accompanying this report refer to datum 0.39 foot above mean sea at Sandy Hook (= B. W. S. datum for Catskill aqueduct) and 1.72 feet below the zero of the Brooklyn Water Department's levels.

ACKNOWLEDGMENTS

To Mr. John R. Freeman, Consulting Engineer, under whose general supervision the Long Island investigations have been carried on, is due the main features of the plan for the development of the Suffolk County supply, here proposed.

Acknowledgments should be made to the Department of Water Supply for their co-operation in the studies that have been made of the Brooklyn water-works during the past year. Their records have been open to the inspection of the engineers of this Board, and every facility has been given in the field to fully study the operation of their works.

Much assistance has been rendered by Headquarters department of the Engineering bureau of this Board in completing the final maps and diagrams for this report. Mr. Alfred D. Flinn, Department Engineer at Headquarters, has himself given many valuable suggestions and much encouragement during the entire progress of the investigation and, in temporarily assigning several of his assistants, notably Robert W. Steed, Mechanical Engineer, Horace Carpenter, Electrical Engineer, and Roger W. Armstrong, Assistant Engineer, to special problems and estimates, he has made possible the early completion of this work.

The studies of Mr. George C. Whipple, Sanitary Expert and Biologist, on the physics of Long Island soils, and his report on oyster culture in the Great South bay, which is pre-

sented as one of the appendices of this report, have been of the greatest importance in rounding out the Long Island investigations.

The zeal and efficiency that have been displayed during the past year by L. B. Stebbins, Francis S. Pecke, Charles W. Tarr, John L. Hildreth, Jr., Assistant Engineers, and others in the Long Island department should be here recorded. Particularly is the work of Mr. William W. Brush gratefully acknowledged. Mr. Brush's long familiarity with the Brooklyn water-works and his understanding of the ground-water problems that were being studied, made his services invaluable during these Long Island investigations. In addition to Appendix 4 on the Brooklyn works, he prepared under my direction the material on the yield of the Brooklyn watersheds, which is given in the main report and in Appendix 1, also the maps and estimates on damages that have been paid on account of the operation of the Brooklyn works, which are included in Appendix 16.

Respectfully submitted,

WALTER E. SPEAR,
Division Engineer.

APPENDIX 1

AMOUNT OF GROUND-WATER AVAILABLE FROM SUFFOLK COUNTY SOURCES

BY WALTER E. SPEAR, DIVISION ENGINEER

All investigations have shown that the source of both the surface and underground waters on Long Island is to be found in the rains and snows that fall upon its surface. The amount of this precipitation, or the magnitude of the ultimate source of water-supply should, therefore, be determined in any study of the yield of the Suffolk County watersheds.

RAINFALL ON LONG ISLAND

Rainfall observations have been made on Long Island since 1826, when the records of the New York Academy stations were begun. The design and manner of exposure of the early rain-gages used at the Academy stations, as well as those later adopted at the Army Post stations, must have resulted in an underestimation of the amount of rainfall. Not until 1854, when the observations of the Smithsonian Institution began, were instruments and methods of observation adopted that gave results comparable with the rainfall records of the present day. The work of the Smithsonian Institution was continued by the U. S. Signal Service and later, in turn, by the U. S. Weather Bureau.

In addition to the records made by the State and the National Government, the Brooklyn Water Department has maintained a rainfall station at Hempstead storage reservoir since 1879 and has secured other valuable rainfall records elsewhere in western Long Island. The Burr-Hering-Freeman Commission established some stations in 1903, and the Board of Water Supply began observations at others in 1907, but the records of these stations cover too short a period to be of much value. Descriptions of the rainfall stations established prior to 1903 are given in the report of the Burr-Hering-Freeman Commission, pages 681 to 703.

The rainfall stations that have been maintained on Long Island and the adjacent shores are tabulated in Table 3, to-

gether with the periods of observation and the average rainfall during these periods. From these data the normal rainfall at each station for a term of 71 years has been computed. These normal rainfalls have been plotted on the map of Long Island, Sheet 5, Acc. 5035, and iso-hyetals, or lines of equal rainfall, have been drawn, giving due weight to the length of the record and to the character of the observations at each station.

The records of precipitation within the proposed Suffolk County watersheds are meagre, but the records from the stations on the north shore and in eastern Suffolk county are sufficient to fix the lines of equal rainfall within these watersheds.

It appears from the rainfall map that the normal precipitation on the proposed Suffolk County watersheds averages about 45 inches depth per year, while that on the watershed of the Ridgewood system in western Long Island averages only 44 inches. The lower rainfall in western Long Island may perhaps be explained by the lower elevation of the ground there and the abstraction during easterly storms of some of the moisture from the westerly moving rain clouds in passing over the higher hills of Suffolk county.

These estimates of normal rainfall may possibly be in error two or three per cent., but the evidence surely points to a greater precipitation in Suffolk county over that in western Long Island. This is most important in estimating the probable yield of the Suffolk County sources from the present delivery of the Ridgewood system in Nassau and Queens counties.

CHARACTER OF SUFFOLK COUNTY WATERSHEDS

Having determined the amount of rainfall on these Suffolk County watersheds, it is important to understand the character of the surface soils and substrata on which depends the percentage of the rainfall that reaches the water bearing strata and becomes available as ground-water.

Surface Geology

The surface soils and substrata in Suffolk county, with little exception, are of glacial origin, although the deeper strata on which depend the main outlines of the island are said

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TABLE 3

Summary of Precipitation Records, Long Island and Vicinity

Station	Observer	Date of Observation From	Date of Observation To	Length of Record Years	Average Rainfall during this Period Inches	Probable 71-year Mean 1836–1907 Inches	Quality of Record Considering Exposure of Gage, Character of Observation, etc.
Bellport, N. Y.	Smithsonian Institution	1858	1861	3	42.21	40.59	......
Block Island, R. I	U. S. Weather Bureau	1880	1907	27	44.11	43.25	......
Brentwood, N. Y.	U. S. Weather Bureau (Vol.)	1882	1889	3	54.51	53.44	Fair
Bridgeport, Conn.	U. S. Weather Bureau (Vol.)	1894	1907	10	49.22	49.72	......
Brookhaven, N. Y.	Smithsonian Institution	1865	1882	15	47.60	45.33	......
Brooklyn, N. Y.	New York Regents, 1826 to 1872, Department of Water Supply, 1894 to 1907	1826	1907	53	43.67	44.11	Fair
Cutchogue, N. Y.	U. S. Weather Bureau (Vol.)	1899	1907	8	47.68	47.21	Good
Easthampton, N. Y.	New York Regents	1828	1844	16	37.56	40.37	Good
Englewood, N. J.	......	1896	1907	7	50.44	49.94	......
Flushing, N. Y.	Smithsonian Institution	1876	1884	7	43.35	46.61	......
Hempstead storage reservoir, N. Y.	Brooklyn Department of Water Supply	1879	1907	28	43.84	42.98	Excellent
Jamaica, N. Y.	New York Regents	1826	1865	39	39.84	41.50	Good
Mt. Pleasant, N. Y.	......	1877	1885	8	33.68	37.42	......
Narragansett Pier, R. I.	......	1883	1907	24	46.64	44.85	......
Newark, N. J.	......	1844	1907	63	47.47	47.00	......
New Haven, Conn.	U. S. Weather Bureau	1879	1907	28	45.60	44.71	......
New London, Conn.	U. S. Weather Bureau	1871	1907	31	45.96	45.06	......
New York, N. Y.	......	1836	1907	71	45.83	45.83	......
Norwalk, Conn.	U. S. Weather Bureau (Vol.)	1892	1907	14	45.63	46.09	......
Oyster Bay, N. Y.	......	1834	1838	2	40.01	43.49	......
Paterson, N. J.	......	1892	1907	15	50.87	50.37	......
Ridgewood pumping-station	Brooklyn Department of Water Supply	1896	1907	4	40.66	42.35	Fair
Ridgewood reservoir	Brooklyn Department of Water Supply	1897	1907	10	43.67	41.99	Excellent
River Vale, N. J.	......	1893	1906	13	49.50	49.01	......
Sag Harbor, N. Y.	......	1854	1858	2	49.86	48.64	......
Setauket, N. Y.	U. S. Weather Bureau (Vol.)	1886	1907	21	47.76	45.49	Good
Southampton, N. Y.	U. S. Weather Bureau (Vol.)	1891	1907	6	47.04	46.12	Good
Willetts Point, N. Y.	Post Surgeon, U. S. Army	1870	1900	18	44.60	42.88	Fair

to be much older than the glacial epoch. The principal features of the topography of western Long Island are the two well-marked ranges of hills, the so-called "backbone" of the island, which represent terminal moraines of the Great North American glacier.

Only the southerly morainal ridge comes within the Suffolk County watersheds that are being considered. This range of hills has an average elevation of 100 to 200 feet and is made up of irregular summits separated by deep ravines and kettle holes. The latter frequently contain small ponds and the ravines are often occupied by rivulets during wet seasons. This southerly moraine is evidently older than the northerly one and its slopes appear to have been somewhat covered by the outwash of sand and gravels from the retreating ice sheet. This outwash filled and leveled up the depression between the two moraines, and much escaped with the water to the south over the broad plains of southern Suffolk county.

These sandy outwash plains make up 75 per cent. of the area of the proposed Suffolk County watersheds and have, on the whole, a wonderfully smooth and uniform slope of about 15 feet to the mile southerly from the moraines. The only considerable depressions in these outwash plains are the valleys that appear to have been occupied during the glacial epoch by the larger streams made up of melting ice from the face of the glacier. The present streams that are found in these valleys—the Carll's river, Connetquot brook, Patchogue river, Carman's river and Peconic river—are evidently insignificant compared to the great volumes of water that once occupied them, although these streams are, nevertheless, the largest now on Long Island and the only water surfaces in the outwash plains far from the low marshy shores near the sea.

Character of Surface Soils and Vegetation

The surface of the southerly morainal ridge is covered by stony loams somewhat compact and only moderately well underdrained. The general appearance of the surface of these hills differs little from that of northern New York or New England districts of similar glacial origin, and the percentage of surface run-off is doubtless much the same.

The soils of the outwash plains, on the other hand, are sandy and porous. With the exception of the more loamy soils along the south shore, and in the narrow valleys of the

larger and longer streams, these plains support only thin and stunted growths of scrub oak and pine. Hardly more than 15 per cent. of the whole area has ever been cultivated. Frequent forest fires have prevented the accumulation of the humus necessary to the growth of crops, and these soils are consequently very open and leachy, and are not productive unless the natural deficiencies are artificially supplied.

Run-off from Watersheds

This leachy, porous soil covering of the Suffolk County plains make them an ideal catchment for a ground-water supply. The surface run-off is ordinarily almost negligible and the evaporation is small; a large portion of the rains and snow sinks quickly through the scanty layer of vegetable mold, percolates rapidly through the coarse soil below and quickly reaches the deep porous substrata beyond the reach of vegetation and surface evaporation. Most of the surface run-off from the more impervious morainal hills is necessarily delivered in the outwash plains that surround them and is similarly conserved in the deep sands and gravels.

It will be shown that only at very infrequent intervals do floods occur from rains and snows on frozen ground that are at all comparable with those on the watersheds of many surface-water supplies. Ordinarily, the frost does not penetrate into these sandy soils over 12 or 18 inches, and this remains only a few days in the comparatively mild winters of southern Long Island. In the scrub oak and pine barrens, that cover a large part of the outwash plains, standing water is seldom seen on the surface, even in midwinter or spring, except, perhaps, in the highways where the gravels have been ground up and consolidated under the traffic.

LIMITS OF CATCHMENT AREA

Surface Drainage Area

The surface drainage area tributary to the collecting works along the south shore of Suffolk county and in the Peconic valley amounts to 370 square miles and comprises the entire surface of the island south of the summit of the northerly moraine, with the exception of the drainage area of the Nissequogue river, a deep, northerly sloping valley tributary to Long Island sound. Much of the area between the northerly

and southerly moraines is in the surface watershed of the Carman's river, the largest stream in Suffolk county.

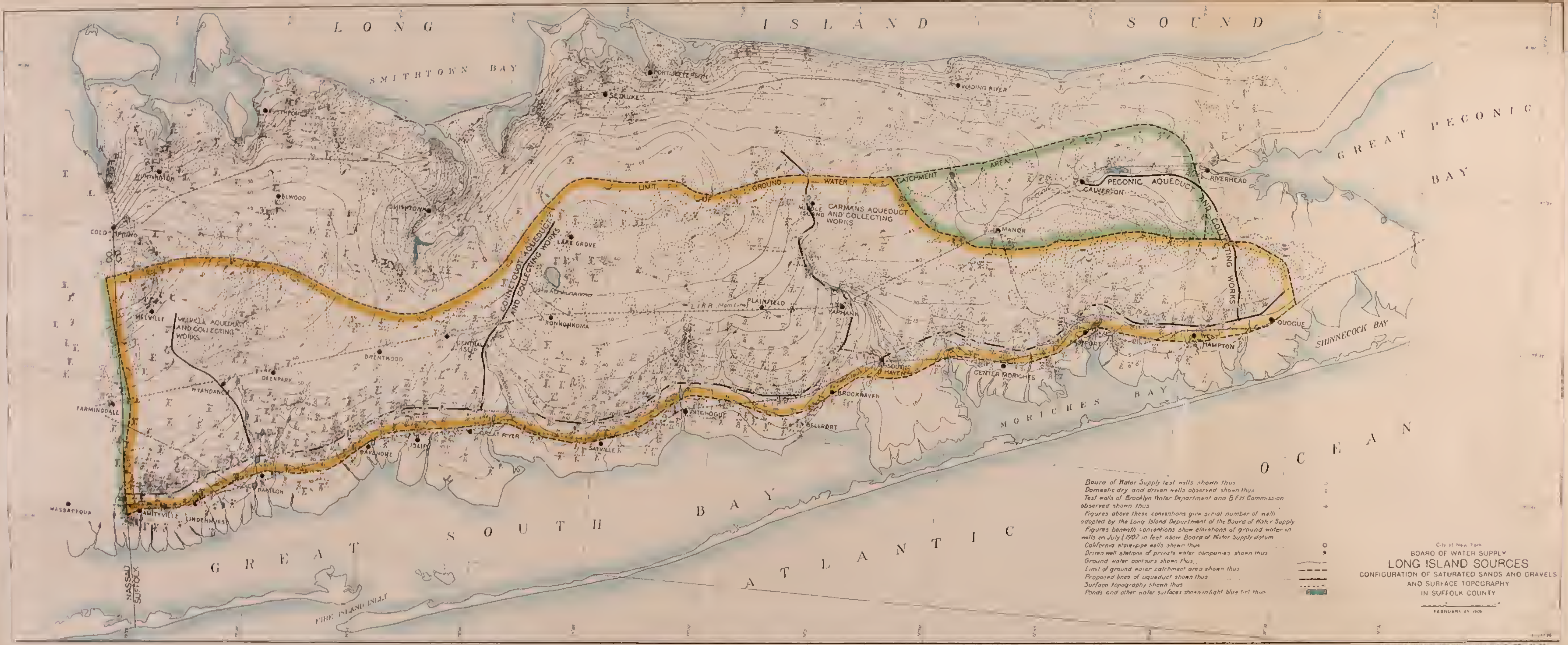
Ground-Water Catchment

It has been pointed out, however, that surface run-off ordinarily takes place from only a small portion of the Suffolk County watersheds within the limits of the morainal hills, where the soils are somewhat impervious. The rains that percolate through the coarse soils and substrata of the outwash plains are collected as ground-water in the deep strata below, and thence flow away to the sea in the saturated sands and gravels. The direction of this ground-water movement has not, necessarily, any relation to the slope of the ground surface which governs the direction of the surface run-off.

Sheet 6, Acc. 5596, exhibits the configuration of the water-table or the surface of the saturated sands and gravels in Suffolk county as determined by the test-borings and surveys during the past year. The slope of the water-table, which is shown by the ground-water contours, indicates the direction of the ground-water movement in the pervious strata, and the summits of the ground-water surface in central Suffolk county represent the divide from which the ground-water flows in a general northerly or southerly direction to the sea.

The ground-water contours shown here define, however, only the main surface of saturation. In the moraines, local beds of clay and boulder till maintain elevated water-tables that are much higher and quite independent of the main surface of saturation. Between these elevated or "perched" water-tables, as termed by the U. S. Geological Survey, and the main water-table below, the strata are only partially saturated. It is a common expedient in draining elevated swamps in the hills to connect the ditches or underdrains with wells dug through the underlying clay bed, in order that the drainage may disappear in the partially saturated sands below.

The surface of the main water-table beneath the moraines must necessarily be irregular as a result of the lack of uniformity of delivery of the water from the surface through the occasional natural or artificial channels. The steepness in the slope of the water-table which is noticeable here and there about the edges of the morainal hills suggests of the discharge at these points of surface drainage from the semi-impervious ridges to the porous surface of the outwash plains.



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There are but few observations upon the surface of the main water-table beneath the high and compact morainal ridges, and the ground-water contours there are drawn in a general way from the observations in wells outside of these areas. This lack of information in these areas does not appreciably affect the accuracy of the determination of the ground-water catchment. The few wells in the doubtful area between the Nassau County line and Elwood indicate that the ground-water summit is not far from the surface divide of the southerly moraine. Considering the semi-impervious character of the morainal hills, the ground-water divide in this section can be considered, without sensible error, to coincide with the surface divide.

The surface of saturation and the ground-water divide elsewhere are well defined. Between Elwood and Lake Grove the drainage of the ground-water to the deep valley of Nissequogue river deflects the ground-water divide south, almost to the Main line of the Long Island railroad at Brentwood. From Lake Grove to Middle Island the ground-water summit is considerably north of the surface divide of the southerly moraine in the center of the island, as a result of the apparent lack of free drainage toward Long Island sound, through the fine gray sands that underlie the surface strata. East of Middle Island the drainage to the Peconic river diminishes the amount of ground-water movement toward the south shore and deflects the limit of the catchment area of the southern Suffolk County sources to the south, where it evidently coincides with the summit of the southerly moraine.

The southerly limit of the ground-water catchment area from Amityville to Quogue is fixed by the probable limit of inflection of the water-table toward the line of the proposed aqueduct during the operation of the collecting works there.

The outline of the ground-water catchment of the Peconic Valley sources can readily be drawn by means of the existing points of observations of the water-table and the ground-water contours drawn through them.

Area of Ground-Water Catchment

The ground-water map shows that the width of the ground-water catchment of the southern Suffolk county sources out to the Carman's river is about nine miles, with the exception of that portion near Bayshore and Islip. Beyond the Forge

river the catchment area tributary to the south shore development narrows to about four miles in width, and the amount of water to be obtained beyond Eastport would hardly repay the cost of development, but for the opportunity afforded by the extension of the main south shore aqueduct to Westhampton to readily secure the ground-waters of the Peconic valley.

The total area of ground-water catchment tributary to the proposed collecting works in southern Suffolk county and the Peconic valley is 332 square miles. Of this, the proposed works in southern Suffolk county would drain 294 square miles, and those in the Peconic valley 38 square miles.

It should be noted that this is about 40 square miles less than the total surface drainage area of 370 square miles that would be tributary to the proposed works if the surface of Suffolk county were as impervious, for example, as the Croton watershed.

YIELD OF SUFFOLK COUNTY WATERSHEDS

Disregarding occasional winter flood flows from the frozen surface of the Suffolk County watersheds and the run-offs from the rainfall that falls upon the low, swampy lands bordering upon the streams, the Suffolk County streams within the watersheds now being considered are fed solely by ground-water. These streams only exist in dry weather because their beds are below the general level of the saturated sands and gravels in their immediate vicinity.

Only the ground-waters, however, in the upper strata near these streams drain into them. The southerly ground-water movement between and parallel with the valleys in which these surface streams occur does not reach the streams, and the deep water bearing gravels underlying the whole island carry much of the underflow directly to the bays and to the ocean beyond. The flow of the surface streams represents, therefore, only a part of the yield of the Suffolk County watersheds.

Visible Yield of Watersheds

While there is no intention to directly divert to New York City any of the surface-waters of Suffolk county, the waters which make up the flow of the streams are a part of the entire yield of the watersheds, and represent the only portion of this yield that can be measured before the proposed ground-water collecting works are in operation.

Surface Run-off in 1907

The flows of the Suffolk County streams in 1907, together with the rainfall and the elevations of the shallow ground-waters near the gaging stations, are shown on Sheets 8, 9 and 10, Accs. L 609, L 610 and L 611. The location of the gaging stations and the character of the measurements are given in Table 4, following which are Plates 1 to 11, showing typical gaging stations. The hydrographs of the Suffolk County streams show that the maximum run-offs occur in winter and spring, the lowest in summer and fall, and that these flows, excepting during brief periods of heavy rain, are proportional to the hight of the ground-water in the vicinity of the streams. The rainfall in 1907 in eastern Long Island was somewhat below the normal.

The total average discharge, during the past year, of all the Suffolk County streams that cross the proposed line of collecting works, is estimated from the above gagings at 151 million gallons per day. The flows of the individual streams are shown in Table 5.

In this table are given only the streams that are intercepted by the line of the proposed collecting works. The small brooks that drain the saturated sands and gravels south of the line of the proposed collecting works are not included, as these streams are fed by their immediate watersheds independently of the upland catchment area.

The entire surface run-off of the Suffolk County watersheds will perhaps average, in course of years, from 100 to 200 million gallons per day, depending upon the magnitude and the distribution of the rainfall. The past year was one of nearly normal rainfall, and the run-off approximates the average yield of the streams, which is equivalent to about 450,000 gallons per day per square mile of the whole catchment area of 332 square miles tributary to the proposed Suffolk County collecting works. This agrees with the natural unit run-off of the surface streams in the "new watershed" of the Ridgewood system.

Large Supply from Surface Streams Impracticable

The estimate of average surface run-off of these Suffolk County streams includes the comparatively large flows of win-

ter and spring; the minimum discharges are much less than this, although immensely greater than the minimum discharge from watersheds of equal area having little ground-water storage. The gagings of 1907 indicate that the lowest flows aggregated 82 million gallons per day and were therefore somewhat over one-half the average as shown in Table 5.

The stream measurements of 1894 made by the Brooklyn Water Department at the end of an extremely dry summer show on most of these streams, somewhat smaller flows than measured in 1907, but other streams apparently yielded more than the lowest flow of the past year. The total of 90 million gallons per day agrees very well with the results of the gagings of 1907. The water-table has been sustained by an ample rainfall since 1885 and the measurements of 1894 and 1907 do not probably represent the minimum discharge of the Suffolk County streams. During a long period of deficient rainfall, when the ground-water surface would be lower than during the last twenty years, the minimum flow of all these Suffolk County streams might be only 50 million gallons per day, or even less.

It is evident that works in southern Long Island for the collection of a supply of surface-water alone, would provide at times only a comparatively small yield unless large storage reservoirs were provided. These are not practicable because of the unfavorable topography of southern Long Island, the pervious character of the surface and substrata, and the growths that occur in open reservoirs of mixed surface and ground-water. Large covered reservoirs are not possible because of their cost. In spite of the wonderfully sustained dry weather flows of these Suffolk County streams, they could not, in the absence of storage reservoirs, be made to yield a continuous supply greater than one-third the average run-off of the streams, and this surface run-off represents only a portion of the entire yield of the watershed. The ground-water underflow promises a larger, more uniform, and a better supply than could be obtained from the surface-waters.

Volume of Deep Underflow

The rate of seaward flow of the large volumes of ground-water in Suffolk county that does not enter the surface streams

TABLE 4

Gaging Stations on Suffolk County Streams, 1907

Stream	Location of Stream in Feet from Nearest Railroad Station	Location of Gaging Station	Method of Measurement	Length of Weir in Feet	Number End Contractions	Width of Approach in Feet	Depth of Approach Below Crest of Weir in Feet
Massapequa	2,000 feet east of Massapequa	1,000 feet north of railroad	Recording gage with sharp crested weir	14.893	....	14.89	2.46
Santapogue, East branch	7,000 feet east of Lindenhurst	North end of 30-inch cast-iron pipe culvert under railroad track	Recording gage with sharp crested weir	5.010	....	5.01	2.5
Carll's river, East branch	2,000 feet west of Babylon	North side of St Udall's road at head of Southard's pond, 6,000 feet north of Long Island railroad	Recording gage with sharp crested weir	15.000	....	15.00	2.2
Carll's river, West branch	2,000 feet west of Babylon	North side of St Udall's road at head of Southard's pond, 6,000 feet north of Long Island railroad	Recording gage with sharp crested weir	5.991	2	10.0	1.5
Sampawams creek	3,000 feet east of Babylon	South end of 3-arch concrete culvert under railroad	Recording gage with sharp crested weir	7.890	2	37.0	1.2
Sampawams creek	3,000 feet east of Babylon	South side of Muncey's road culvert, 5,000 feet north of railroad	Current meter				
Penataquit creek	2,000 feet east of Bay Shore	South end of culvert under railroad	Recording gage with sharp crested weir	6.010	2	11.0	0.68
Orowoc creek	4,500 feet west of Islip	South side of railroad on property of W. H. Moffitt	Recording gage with sharp crested weir	5.000	2	12.0	1.5
Orowoc creek	4,500 feet west of Islip	South end of culvert, Dosser boulevard, 250 feet north of railroad	Current meter		....		....
Dosseo creek	2,500 feet west of Islip	North end of culvert under private road, 750 feet south of railroad	Recording gage with sharp crested weir	8.030	....	3.03	1.9
Dosser creek	2,500 feet west of Islip	South end of culvert, Dosser boulevard, 250 feet north of railroad	Current meter				
Champlin creek	2,000 feet east of Islip	South end of culvert under railroad	Recording gage with sharp crested weir	10.000	2	21.0	1.3
Connetquot river, West branch	6,000 feet east of Great River	South end of flume under South Country road, 300 feet north of railroad	Current meter	....	....	....	....
Connetquot river, East branch	7,000 feet east of Great River	South end of flume under South Country road, 200 feet north of railroad	Current meter	....	....	....	....
Brown's river, West branch	3,000 feet east of Sayville	North end of culvert under railroad	Current meter	....	....	....	....
Brown's river, East branch	5,000 feet east of Sayville	South end of brick arch culvert, South Country road, 400 feet north of railroad	Current meter	....	....	....	....
Tuthill creek	3,000 feet west of Patchogue	South side of South Country road, outlet to West pond, 1,500 feet north of railroad	Sharp crested weir, head measured from B. M.	3.9	....	3.9	0.6
Patchogue river 1	1,500 feet west of Patchogue	In woods 7,000 feet north of railroad, just south of proposed road crossing on property of Forrest Lakes Realty Co.	Current meter	....	....	....	....
Patchogue river 2	1,500 feet west of Patchogue	North end of flume outlet to Mill pond at Canaan, 9,000 feet north of railroad	Current meter	....	....	....	....
Swan river	6,000 feet east of Patchogue	North end of 18 inch pipe culvert under Barton avenue, 8,000 feet north of railroad	Current meter	....	....	....	....
Mud creek	10,000 feet east of Patchogue	South end of flume, outlet to Robinson's pond, South Country road	Rough weir with 2 scale readings daily	4.27	....	4.27	2.0
Carman's river—1	10,000 feet east of Brookhaven	South side of South Country Road bridge, 1,500 feet north of railroad	Current meter	....	....	....	....
Carman's river 2	10,000 feet east of Brookhaven	South side of Port Jefferson Avenue bridge, Yaphank, below upper pond, 8,000 feet northwest of Yaphank railroad station	Current meter	....	....	....	....
Forge river	2,000 feet east of Mastic	South end of flume, outlet of West pond, South Country road, 1,800 feet north of railroad	Recording gage with sharp crested weir	4.554	....	4.554	2.00
Terrell river	5,000 feet east of Center Moriches	South end of 48-inch pipe culvert under railroad	Current meter	....	....	....	....
Seatuck creek, West branch	1,000 feet east of Eastport	South end of flume under South Country road	Recording gage with sharp crested weir	3.012	....	3.012	5.5
Seatuck creek, East branch	4,000 feet east of Eastport	South end of two 30-inch pipes under railroad	Current meter	....	....	....	....
Peconic river	3,500 feet west of Calverton	North side of railroad, Main Line division	Current meter with recording depth gage	....	....	....	....

PLATE 1

Weir station on Santapogue creek, on Montauk division, Long Island railroad, about one-half mile west of Babylon.

PLATE 2

Weir station on Carrl's river, West branch, about one-half mile north of Babylon.

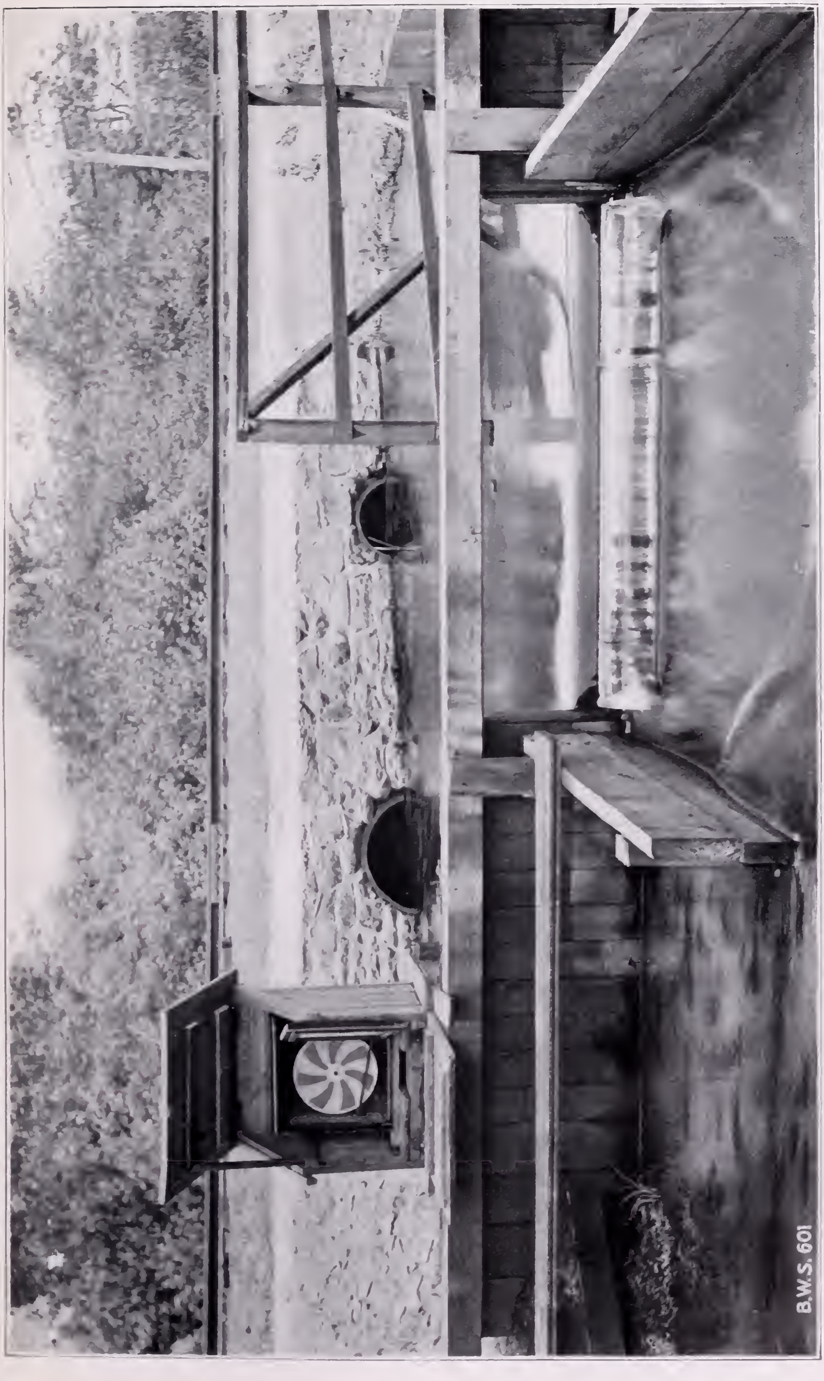
Weir station on Carll's river, East branch, about one-half mile north of Babylon.

Weir station on Sampawam's creek, on Montauk division, Long Island railroad, between Babylon and Islip.

PLATE 5

Weir station on Penataquit river, on Montauk division, Long Island railroad, Bayshore.

PLATE 6



Weir on Orowoc creek, Montauk division, Long Island railroad, Islip; dial gage shown as used on two weir stations.

PLATE 7

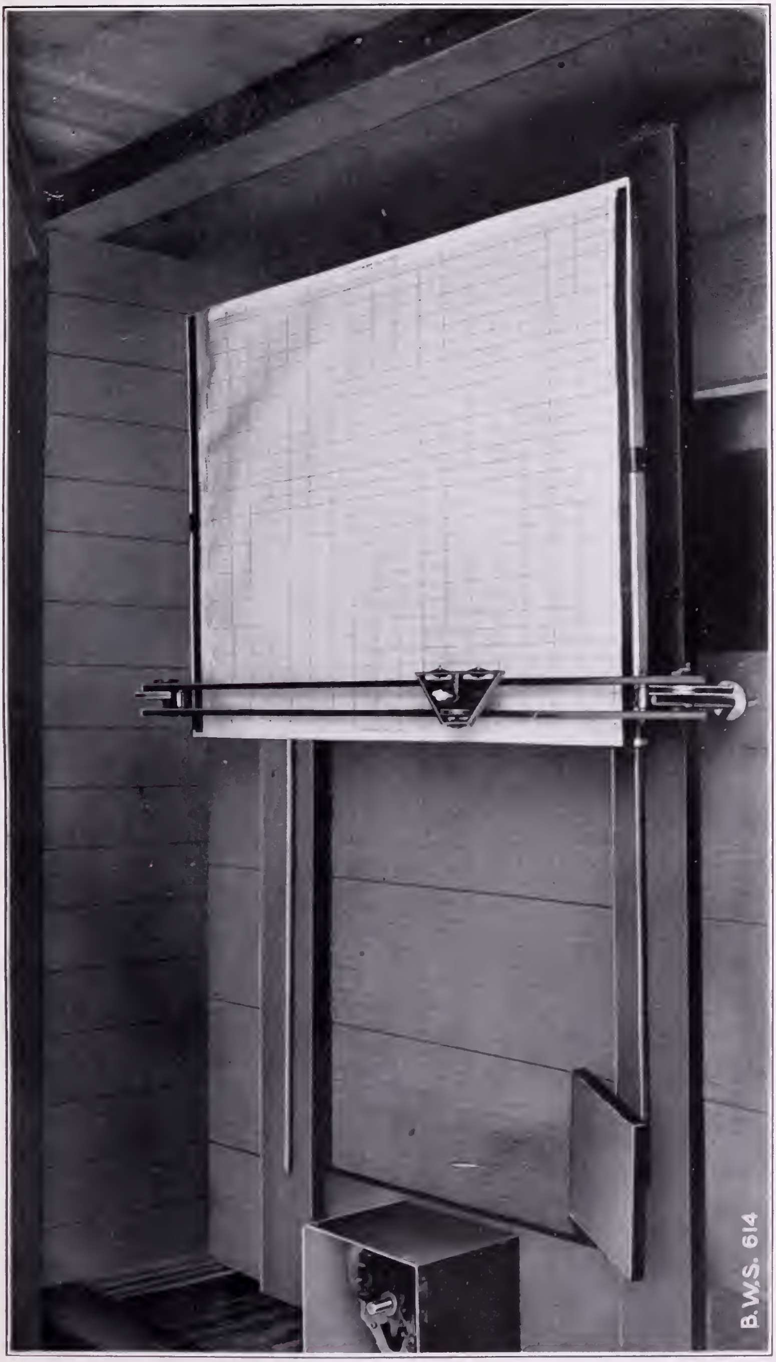
Recording weir station on Doxsee creek, one-half mile west of Islip, showing fine rule scale for obtaining head of water on crest.

Weir station on Champlin creek, on Montauk division, Long Island railroad, one-half mile east of Islip.

Weir station on Forge river, South Country road, Moriches.

PLATE 10

Weir station on Seatuck creek, at South Country road, Eastport.



Recording gage at weir station on Seatuck creek. This type of platform gage was used at many of the stations.

TABLE 5

Surface Run-Off of Suffolk County Watersheds. On Line of Proposed Aqueduct and Collecting Works

Stream	Average Run-off in 1907 in Million Gallons Per Day from Gagings of B. W. S.	Minimum Discharge of Streams in Million Gallons Per Day				
		Date 1907	Discharge from Gagings of B. W. S.	Discharge from Gagings of Brooklyn Water Department		
				Date 1894	Actual Measurements	Corrected to aqueduct line
Santapogue........	3.52	Sep. 18	1.13	Sep. 16	1.09	0.98
Carll's river........	17.20	" 1	9.70	Aug. 28	7.45	7.45
Sampawams creek..	6.40	Oct. 24	2.85	Sep. 8	2.21	1.86
Penataquit creek...	3.32	Aug. 29	1.47	" 1 to 7	1.40	1.20
Orowoc creek......	3.51	Aug. 18	1.50	" 1 to 3	0.72	0.66
Doxsee creek.......	0.80	Sep. 19	0.14	" 2 to 5	0.31	0.13
Champlin creek....	3.95	Oct. 24	1.98	" 22	3.11	2.11
Connetquot brook..	32.70	Sep. 9	23.85	Aug. 31 to Sep. 7	15.92	15.80
Browns river.......	3.85	Sep. —	2.39	Aug. 26 to 28	2.09	1.82
Tuthill's creek.....	2.88	" 17	1.66	Aug. 19	2.34	1.71
Patchogue river....	9.43	Jul. 9	4.90	Sep. 9	11.10	10.05
Swan river.........	1.92	Oct. 15	1.18	" 3	6.20	5.80
Mud creek.........	2.62	" 19	1.81	" 1	1.04	0.94
Carman's river.....	*36.20	Sep. 17	*20.10	Aug. 23	26.68	26.68
Forge river........	3.91	" 30	2.80	Oct. 8	3.43	3.19
Terrell river........	1.35	" 9	0.69	Sep. 25 to Oct. 4	0.66	0.49
Seatuck creek......	3.27	Oct. 14	0.70	Sep. 30	1.45	1.35
Total in southern Suffolk county...	**136.83**	....	**78.85**	....	**87.20**	**82.22**
Peconic river at Calverton.......	14.65	Sep. 1	3.50	....	*3.00	*3.00
Total of all streams.	**151.48**	....	**82.35**	....	**90.20**	**85.22**

*Estimated

can only be determined with accuracy by pumping experiments on a scale approximating the final development. Measurements of ground-water movement were carried on in Nassau county in 1903 by the U. S. Geological Survey under the direction of the Burr-Hering-Freeman Commission. These underflow measurements were made by the so-called Slichter method, on a section parallel with the south shore about seven miles in length, between East Meadow supply pond and the Massapequa stream, but the results, while of great interest, were not satisfactory. The water bearing strata there were found to be so lacking in uniformity and so separated by irregular beds of clay and semi-impervious strata of fine sand, that it appeared to be physically impossible to make enough measurements on the section to obtain an accurate estimate of the entire southerly ground-water movement. This method of ground-water measurements, which was first devised by Thiem in Germany, is no longer employed there to any extent. Pumping experiments on a large scale are considered necessary for the purpose of estimating the yield of ground-water sources.

Estimate of Suffolk County Yield on Basis of Ridgewood System

With the full knowledge of the operation and the yield of the Ridgewood system in western Long Island, large and expensive pumping experiments in Suffolk county appeared entirely unnecessary during the present investigations, because the character of the surface and the climatic conditions in western Long Island are almost identical with those in the easterly portion. The small differences that exist between the conditions in the westerly and the easterly portions of the island affecting the ground-water yield appear to indicate a larger yield from the Suffolk County watersheds than from those of the Ridgewood system.

The surface soils in Nassau and Queens counties are probably finer than those in eastern Long Island, because of the greater areas under cultivation in the vicinity of New York City, so that the percentage of collection on the Suffolk County watersheds should be greater than on the watershed of the Ridgewood system. Furthermore, the rainfall in Suffolk county may possibly average one inch greater than on the Ridgewood watersheds, and the percolation should be greater in Suffolk county by very nearly this amount because

TABLE 6

Yield of the Ridgewood System of the Brooklyn Works in Queens and Nassau Counties, from 1897 to 1907 Inclusive

From Records at the Brooklyn Office of the Department of Water Supply, Gas and Electricity

Month	Rainfall in Inches Depth at Hempstead Storage Reservoir	Average Monthly Yield of Old Watershed (67 Square Miles) in Million Gallons per Day, not Including Ground-Water Waste: Ground-water delivered to conduit	Surface water entering conduits	Surface water wasted at supply ponds	Total yield including surface waste	Average Yield of Old Watershed per Day per Square Mile in Gallons
1897						
January	2.27	30.0	11.3	7.0	50.1	750,000
February	2.71	30.5	11.4	10.5	52.4	780,000
March	3.11	29.0	11.9	6.3	40.2	690,000
April	3.34	28.6	12.3	8.1	48.9	730,000
May	4.64	31.1	10.2	8.0	49.3	730,000
June	7.17	34.2	10.0	0.8	51.0	760,000
July	11.58	29.8	17.1	7.4	51.2	810,000
August	2.02	28.5	15.1	1.4	48.0	720,000
September	1.51	28.1	10.2	2.2	40.0	750,000
October	1.51	29.3	19.0	1.2	50.4	750,000
November	5.00	27.2	14.8	2.7	44.7	670,000
December	4.80	21.3	18.1	4.8	47.1	700,000
Totals	**46.41**	**351.7**	**171.3**	**69.3**	**593.3**	**8,830,000**
Average	**3.87**	**29.3**	**14.3**	**5.8**	**49.4**	**740,000**
1898						
January	4.12	27.9	17.3	5.2	49.0	740,000
February	4.29	20.0	20.2	7.8	53.0	810,000
March	3.05	11.0	14.8	5.8	51.5	770,000
April	3.09	28.0	15.8	8.0	53.3	800,000
May	8.99	27.7	17.0	12.4	57.1	850,000
June	0.77	22.7	25.7	10.7	50.1	850,000
July	5.13	27.4	20.5	7.1	51.0	820,000
August	4.83	31.1	20.0	0.1	57.3	800,000
September	2.44	32.1	22.8	2.0	57.7	800,000
October	5.81	28.5	22.1	1.5	55.0	830,000
November	10.00	25.5	40.0	8.0	102.1	930,000
December	2.40	21.7	38.0	15.7	70.0	1,180,000
Total	**61.22**	**330.7**	**385.7**	**94.6**	**691.0**	**10,310,000**
Average	**4.2**	**27.6**	**32.1**	**7.9**	**57.6**	**860,000**
1899						
January	4.22	20.1	27.5	20.0	77.1	1,151,000
February	5.02	31.5	25.0	16.5	74.1	1,110,000
March	7.70	20.0	26.0	11.0	83.6	1,250,000
April	3.17	27.6	27.3	31.2	70.0	1,180,000
May	1.70	20.0	31.3	11.0	60.0	1,011,000
June	2.21	28.7	24.0	7.7	60.5	900,000
July	5.07	27.0	35.8	0.2	50.1	800,000
August	3.50	28.5	21.1	0.1	58.0	800,000
September	5.17	28.8	22.5	6.0	58.0	800,000
October	2.70	28.0	20.5	5.0	54.5	800,000
November	2.00	20.8	10.6		40.4	600,000
December	1.82	28.0	10.0	1.0	48.8	730,000
Totals	**43.60**	**337.3**	**369.6**	**140.7**	**767.6**	**11,463,000**
Average	**3.93**	**28.1**	**24.3**	**11.7**	**64.0**	**960,000**
1900						
January	1.16	28.7	16.9	7.0	52.0	790,000
February	5.01	28.2	19.4	13.1	60.7	910,000
March	3.77	28.5	21.0	13.8	61.3	900,000
April	1.87	27.4	20.8	10.2	58.3	870,000
May	1.11	27.0	20.6	10.8	59.0	880,000
June	1.08	27.5	22.0	0.6	50.0	840,000
July	1.09	28.1	23.8	5.1	50.0	850,000
August	3.70	28.7	20.7	3.6	53.0	790,000
September	2.10	28.7	17.5	2.8	40.0	730,000
October	3.22	20.2	14.5	2.5	40.5	600,000
November	4.16	28.0	10.3	3.2	48.1	720,000
December	2.28	20.3	10.1	4.7	50.0	790,000
Totals	**41.43**	**340.1**	**230.3**	**64.4**	**955.3**	**9,790,000**
Average	**3.45**	**28.3**	**19.9**	**7.0**	**64.5**	**890,000**

Month	Average Monthly Yield of New Watershed (92 Square Miles) in Million Gallons per Day, not Including Ground-Water Waste: Ground-water delivered to conduit	Surface water entering conduit	Surface water wasted at supply ponds	Total yield including surface waste	Average Yield of New Watershed per Day per Square Mile in Gallons	Total Yield of Ridgewood Watershed in Million Gallons per Day (159 Square Miles), not Including Ground-Water Waste: Ground-water delivered to conduit	Surface-water entering conduit	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of Ridgewood Watershed per Day per Square Mile in Gallons
1897										
January	22.2	20.7	0.1	43.0	470,000	53.1	32.0	8.0	93.1	590,000
February	20.8	22.5	4.7	47.8	520,000	51.1	33.0	15.3	100.2	630,000
March	19.6	32.6	0.8	44.0	480,000	39.6	44.5	6.1	90.2	570,000
April	4.9	38.1	1.2	41.5	480,000	33.4	50.7	9.3	93.4	590,000
May	7.6	35.5		43.1	470,000	38.7	45.7	8.0	92.4	580,000
June	12.7	29.9	0.5	43.1	470,000	40.0	39.9	7.3	94.1	590,000
July	7.4	35.0	14.1	56.5	610,000	37.2	52.1	21.4	110.7	690,000
August		43.8	4.2	48.0	520,000	28.5	58.0	8.6	96.0	600,000
September	9.9	31.2		44.0	480,000	38.3	53.4	2.2	93.9	590,000
October	14.6	27.5		42.1	460,000	43.0	47.4	1.2	92.5	580,000
November	15.8	28.2		44.0	480,000	43.0	43.0	2.7	88.7	560,000
December	7.3	36.0	1.0	44.3	480,000	31.0	54.1	5.8	91.4	580,000
Totals	**133.6**	**384.2**	**26.6**	**544.4**	**6,910,000**	**465.3**	**866.6**	**96.9**	**1,136.6**	**7,160,000**
Average	**11.2**	**32.1**	**2.2**	**45.6**	**490,000**	**40.4**	**46.3**	**8.0**	**94.7**	**590,000**
1898										
January		16.5		40.5	510,000	27.2	63.8	5.2	96.1	610,000
February		43.5	8.2	51.5	600,000	26.0	63.7	16.0	105.6	660,000
March		44.1	0.6	53.7	580,000	31.0	58.9	15.3	105.2	660,000
April		42.7	5.2	47.9	520,000	28.0	58.6	14.1	101.2	640,000
May		43.0	26.2	69.2	750,000	27.7	60.0	38.6	126.3	790,000
June		42.1	14.6	56.0	620,000	22.7	68.1	25.3	116.0	730,000
July		12.1	1.5	44.3	480,000	27.3	62.0	8.7	99.2	630,000
August		10.3		40.2	440,000	31.1	60.3	0.1	97.5	610,000
September	0.8	31.9		38.7	420,000	39.2	54.7	2.4	96.4	610,000
October	9.0	27.9	0.1	37.8	410,000	38.1	50.3	4.6	93.2	590,000
November	3.7	29.3	11.8	41.8	400,000	27.2	59.9	19.8	106.9	670,000
December		28.1	31.9	60.1	650,000	21.7	66.7	47.6	139.1	880,000
Total	**20.4**	**482.1**	**103.1**	**591.6**	**6,430,000**	**361.1**	**737.6**	**203.7**	**1,282.6**	**8,070,000**
Average	**1.7**	**36.5**	**9.1**	**49.3**	**540,000**	**30.3**	**60.6**	**16.9**	**106.9**	**670,000**
1899										
January		37.0	26.2	64.0	700,000	20.1	65.4	46.8	141.1	890,000
February		40.0	30.8	71.0	770,000	31.6	65.9	47.3	145.1	910,000
March		40.8	68.1	109.0	1,180,000	28.6	66.8	99.1	192.6	1,210,000
April		38.2	47.2	85.3	930,000	27.5	65.5	71.4	161.3	1,030,000
May		30.7	19.0	55.8	610,000	26.0	68.0	30.9	124.8	790,000
June		41.5	0.0	42.0	460,000	28.7	65.6	8.3	102.5	640,000
July		41.0		40.9	440,000	27.6	66.8	6.2	100.3	630,000
August	9.0	38.6		39.4	430,000	29.1	62.0	6.1	97.4	610,000
September	6.0	34.2		41.1	450,000	35.7	56.7	6.6	99.1	620,000
October	8.2	32.2		40.7	440,000	36.2	52.7	5.0	94.3	590,000
November	10.1	31.1		41.5	450,000	31.2	50.7		87.9	550,000
December	10.8	31.6		42.3	460,000	38.8	47.5	1.9	91.1	570,000
Totals	**37.2**	**446.7**	**191.9**	**873.0**	**7,330,000**	**374.4**	**733.8**	**633.8**	**1,440.8**	**9,040,000**
Average	**3.1**	**36.9**	**16.0**	**66.0**	**610,000**	**31.2**	**61.1**	**37.7**	**120.0**	**760,000**
1900										
January	7.0	34.0		41.0	450,000	35.2	50.9	7.9	93.9	590,000
February	1.0	30.5	5.9	10.1	500,000	29.2	58.9	19.0	107.1	670,000
March		40.6	8.5	40.0	530,000	28.5	62.1	22.3	113.3	710,000
April		10.7	5.8	40.5	510,000	27.1	61.5	16.0	104.8	660,000
May		40.5	1.0	41.5	450,000	27.0	61.1	11.8	100.5	630,000
June		40.0		40.0	430,000	27.5	62.0	6.6	96.0	600,000
July	0.1	30.0		30.1	400,000	34.5	53.8	5.1	93.3	580,000
August	17.1	23.1		40.2	410,000	45.8	43.8	3.0	93.2	580,000
September	17.2	19.0		36.8	400,000	45.9	37.1	2.8	85.8	540,000
October	17.1	18.5		35.6	390,000	40.3	33.0	2.6	82.1	550,000
November	17.0	18.4		35.4	390,000	45.6	34.7	3.2	83.5	530,000
December	10.0	24.9		40.9	440,000	45.4	44.3	4.7	91.5	580,000
Totals	**96.6**	**868.7**	**21.2**	**469.7**	**6,330,000**	**436.9**	**600.6**	**106.6**	**1,148.0**	**7,390,000**
Average	**8.3**	**30.9**	**1.7**	**40.8**	**444,000**	**36.9**	**60.0**	**6.6**	**95.4**	**600,000**

Month	Rainfall in Inches Depth at Hempstead Storage Reservoir	Average Monthly Yield of Old Watershed (67 Square Miles) in Million Gallons per Day, not Including Ground-Water Waste				Avera Yield Old Wate per Day Square in Gali
		Ground-water delivered to conduit	Surface-water entering conduits	Surface-water wasted at supply ponds	Total yield including surface waste	
1897						
January	2.27	30.9	11.3	7.9	50.1	750,(
February	2.74	30.5	11.4	10.5	52.4	780,(
March	3.11	29.0	11.9	5.3	46.2	690,(
April	3.33	28.5	12.3	8.1	48.9	730,(
May	4.64	31.1	10.2	8.0	49.3	740,(
June	3.17	34.2	10.0	6.8	51.0	760,(
July	11.68	29.8	17.1	7.3	54.2	810,(
August	2.62	28.5	15.1	4.4	48.0	720,(
September	1.51	28.4	19.2	2.2	49.9	750,(
October	1.51	29.3	19.9	1.2	50.4	750,(
November	5.00	27.2	14.8	2.7	44.7	670,(
December	4.83	24.3	18.1	4.8	47.1	700,(
Totals	**46.41**	**351.7**	**171.3**	**69.2**	**592.2**	**8,830,(**
Average	**3.87**	**29.3**	**14.3**	**5.8**	**49.4**	**740,(**
1898						
January	4.12	27.2	17.3	5.2	49.6	740,(
February	3.23	26.0	20.2	7.8	54.0	810,(
March	3.45	31.0	14.8	5.8	51.5	770,(
April	3.39	28.6	15.8	8.9	53.3	800,(
May	8.99	27.7	17.0	12.4	57.1	850,(
June	0.77	22.7	25.7	10.7	59.1	880,(
July	5.43	27.3	20.5	7.1	54.9	820,(
August	4.83	31.1	20.0	6.1	57.3	860,(
September	2.44	32.4	22.8	2.4	57.7	860,(
October	5.81	28.5	22.4	4.5	55.4	830,(
November	6.00	23.5	30.6	8.0	62.1	930,(
December	2.36	24.7	38.6	15.7	79.0	1,180,(
Totals	**51.22**	**330.7**	**265.7**	**94.6**	**691.0**	**10,310,(**
Average	**4.3**	**27.5**	**22.1**	**7.9**	**57.6**	**860,(**
1899						
January	4.22	29.1	27.5	20.6	77.1	1,151,(
February	5.02	31.6	25.9	16.5	74.1	1,110,(
March	7.79	26.6	26.0	31.0	83.6	1,250,(
April	1.47	27.5	27.3	24.2	79.0	1,180,(
May	1.79	26.0	31.3	11.9	69.0	1,031,(
June	2.21	28.7	24.0	7.7	60.5	900,(
July	5.07	27.6	35.8	6.2	59.4	890,(
August	3.59	28.5	23.4	6.1	58.0	860,(
September	5.17	28.8	22.5	6.6	58.0	860,(
October	2.76	28.0	20.5	5.0	53.6	800,(
November	2.69	26.8	19.6	.....	46.4	690,(
December	1.82	28.0	16.0	4.9	48.8	730,(
Totals	**43.60**	**337.2**	**289.8**	**140.7**	**767.5**	**11,452,(**
Average	**3.63**	**28.1**	**24.2**	**11.7**	**64.0**	**950,(**
1900						
January	4.45	28.2	16.9	7.9	52.9	790,(
February	5.04	28.2	19.4	13.1	60.7	910,(
March	3.77	28.5	21.9	13.8	64.3	960,(
April	1.87	27.4	20.8	10.2	58.3	870,(
May	4.11	27.6	20.6	10.8	59.0	880,(
June	1.98	27.5	22.0	6.6	56.0	840,(
July	4.69	28.1	23.8	5.1	56.9	850,(
August	3.76	28.7	20.7	3.6	53.0	790,(
September	2.10	28.7	17.5	2.8	49.0	730,(
October	3.22	29.2	14.5	2.6	46.5	690,(
November	4.16	28.6	16.3	3.2	48.1	720,(
December	2.28	29.4	16.4	4.7	50.6	760,(
Totals	**41.43**	**340.1**	**230.8**	**84.4**	**655.3**	**9,790,(**
Average	**3.45**	**28.3**	**19.2**	**7.0**	**54.5**	**820,(**

TABLE 6 (Continued)

Month	Rainfall in Inches Depth at Hempstead Storage Reservoir	Average Monthly Yield of Old Watershed (67 Square Miles) in Million Gallons per Day not Including Ground-Water Waste: Ground-water delivered to conduit	Surface water entering conduit	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of Old Watershed per Day per Square Mile in Gallons
1901						
January	2.21	29.1	16.0	1.7	49.8	[illegible]
February	0.77	20.2	18.6	3.3	40.1	[illegible]
March	6.07	29.5	17.2	5.6	52.3	[illegible]
April	8.05	30.1	14.0	1.6	45.1	[illegible]
May	7.17	30.7	16.6	2.6	49.8	[illegible]
June	[illegible]	30.7	18.9	[illegible]	50.2	[illegible]
July	5.01	30.2	18.1	[illegible]	48.0	[illegible]
August	[illegible]	29.7	15.6	[illegible]	45.0	[illegible]
September	[illegible]	29.1	19.1	2.0	50.2	[illegible]
October	[illegible]	29.1	22.1	1.2	52.4	[illegible]
November	4.28	27.1	17.9	1.9	47.2	[illegible]
December	[illegible]	29.8	17.8	[illegible]	51.9	[illegible]
Totals	49.92	354.6	208.4	26.7	589.7	8,600,000
Average	4.16	29.5	17.2	2.4	49.1	720,000
1902						
January	2.17	29.0	16.9	5.4	51.4	[illegible]
February	4.00	26.8	18.2	28.6	71.8	[illegible]
March	5.01	28.8	[illegible]	[illegible]	81.5	[illegible]
April	[illegible]	28.8	16.5	17.7	[illegible]	[illegible]
May	1.01	22.9	21.8	[illegible]	[illegible]	[illegible]
June	[illegible]	27.1	22.0	1.7	52.8	[illegible]
July	2.42	28.2	19.1	5.4	52.9	[illegible]
August	1.31	26.2	24.1	2.2	51.4	[illegible]
September	5.54	28.1	25.2	1.8	55.1	[illegible]
October	8.08	28.5	14.7	8.4	51.6	[illegible]
November	2.11	28.4	16.4	8.0	53.8	[illegible]
December	7.00	21.8	[illegible]	20.4	[illegible]	[illegible]
Total	51.98	324.6	222.0	142.8	692.4	10,430,000
Average	4.33	27.1	19.2	11.9	58.2	870,000
1903						
January	1.82	19.0	[illegible]	27.0	71.1	[illegible]
February	[illegible]	10.6	[illegible]	21.2	67.2	[illegible]
March	[illegible]	12.2	41.8	31.1	77.1	[illegible]
April	4.98	[illegible]	21.4	28.0	79.6	[illegible]
May	[illegible]	21.9	[illegible]	22.7	[illegible]	[illegible]
June	[illegible]	17.3	[illegible]	20.2	[illegible]	[illegible]
July	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
August	7.67	[illegible]	[illegible]	10.5	[illegible]	[illegible]
September	[illegible]	21.0	[illegible]	8.2	58.1	871,000
October	[illegible]	17.8	[illegible]	[illegible]	62.8	[illegible]
November	[illegible]	[illegible]	28.7	[illegible]	40.8	713,000
December	[illegible]	21.5	[illegible]	[illegible]	50.0	[illegible]
Total	52.14	224.0	315.2	223.7	774.0	11,552,000
Average	4.35	19.6	26.1	18.6	64.2	963,000
1904						
January	[illegible]	[illegible]	[illegible]	8.0	[illegible]	[illegible]
February	[illegible]	25.0	28.2	28.8	82.0	[illegible]
March	[illegible]	21.7	[illegible]	15.0	70.9	[illegible]
April	[illegible]	[illegible]	28.2	7.0	51.4	[illegible]
May	[illegible]	10.2	25.1	5.0	46.7	[illegible]
June	1.77	21.0	24.7	7.3	52.0	[illegible]
July	[illegible]	21.0	20.8	[illegible]	[illegible]	[illegible]
August	10.70	22.8	21.7	20.5	67.0	[illegible]
September	[illegible]	24.0	[illegible]	17.1	65.0	[illegible]
October	[illegible]	[illegible]	28.5	[illegible]	60.3	[illegible]
November	1.87	21.7	30.1	3.6	56.2	[illegible]
December	2.14	22.5	[illegible]	[illegible]	54.8	[illegible]
Total	48.62	264.5	330.6	127.6	722.7	10,789,000
Average	4.05	22.0	27.6	10.6	60.2	900,000

Month	Average Monthly Yield of New Watershed (92 Square Miles) in Million Gallons per Day not Including Ground-Water Waste: Ground-water delivered to conduit	Surface water entering conduit	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of New Watershed per Day per Square Mile in Gallons	Total Yield of Ridgewood Watershed in Million Gallons per Day (159 Square Miles) not Including Ground-Water Waste: Ground-water delivered to conduit	Surface-water entering conduit	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of Ridgewood Watershed per Day per Square Mile in Gallons
1901										
January	15.6	25.6		41.1	450,000	44.7	41.6	4.8	90.9	570,000
February	16.0	24.8		40.9	440,000	45.2	38.4	3.4	87.0	550,000
March	14.6	26.0		40.6	440,000	44.1	43.2	5.7	92.9	580,000
April	2	39.5	11.6	53.1	580,000	31.3	53.0	13.0	98.4	620,000
May		42.1	10.0	50.9	640,000	30.7	58.6	19.4	108.8	680,000
June		41.4	7.2	48.6	530,000	30.7	60.3	7.8	98.7	620,000
July		41.9	2.6	44.5	480,000	30.2	60.0	2.9	93.1	580,000
August	0.5	41.4		42.0	460,000	30.2	57.0	0.6	87.9	550,000
September	9.5	31.8		41.3	450,000	38.0	50.9	2.0	91.6	580,000
October	13.3	26.5		39.8	430,000	42.4	48.6	1.2	92.2	580,000
November	12.9	28.6		41.4	450,000	40.3	46.5	1.9	88.6	500,000
December	11.0	30.9	2.1	44.0	490,000	41.4	48.7	0.4	90.5	610,000
Totals	95.2	401.2	40.4	536.9	5,840,000	449.8	607.7	69.1	1,126.6	7,080,000
Average	7.9	33.5	3.4	44.7	490,000	37.5	50.6	5.7	93.8	590,000
1902										
January		45.7	1.1	46.8	510,000	29.0	62.0	6.5	98.2	620,000
February		47.8	42.2	90.0	980,000	26.8	66.0	70.8	163.8	1,030,000
March		48.4	37.8	86.2	910,000	28.8	64.9	74.1	167.7	1,050,000
April		48.1	19.9	68.0	740,000	28.8	64.6	37.6	131.0	820,000
May		46.2		46.2	500,000	22.0	70.0	4.0	96.7	610,000
June	4.4	39.4		43.8	480,000	31.5	61.4	3.7	96.6	610,000
July	10.4	33.9		44.0	480,000	38.3	53.0	5.4	96.0	610,000
August	12.8	25.7		38.5	420,000	39.0	48.8	2.1	89.8	570,000
September	17.0	21.0		38.0	420,000	45.1	47.1	1.8	94.0	590,000
October	14.2	31.5	0.1	45.8	530,000	42.7	49.2	8.5	100.4	630,000
November	14.1	30.7		44.8	490,000	42.5	47.1	8.9	98.6	620,000
December	8.5	43.8	6.9	59.2	640,000	30.3	63.1	27.3	120.9	760,000
Total	81.1	455.1	108.0	655.2	7,130,000	405.7	698.1	250.7	1,354.6	8,520,000
Average	6.8	38.5	9.0	54.6	590,000	33.8	58.1	20.9	112.8	710,000
1903										
January		51.0	16.00	67.0	735,000	49.0	70.9	43.0	141.9	892,000
February		56.1	12.08	68.0	730,000	40.6	82.5	33.2	135.2	851,000
March		53.1	35.60	88.0	959,000	42.2	85.2	68.7	160.0	1,013,000
April		49.2	41.20	90.4	982,000	19.5	73.6	69.8	162.9	1,024,000
May		54.0	7.20	61.4	664,000	21.9	74.7	29.9	126.5	796,000
June		53.8	10.22	64.0	696,000	17.3	77.0	30.5	124.8	784,000
July		54.3	1.00	55.3	602,000	21.1	76.8	22.0	120.2	756,000
August	0.5	48.5	5.20	54.4	591,000	22.7	71.1	21.8	115.6	727,000
September	1.	46.8	0.01	48.0	522,000	25.2	73.0	8.2	106.4	669,000
October		47.8	1.16	49.2	535,000	17.8	77.6	16.7	112.0	704,000
November		45.0	1.23	46.3	503,000	16.5	73.7	5.8	96.1	604,000
December		48.4	0.26	49.2	535,000	23.5	79.7	5.6	108.8	684,000
Total	1.7	609.3	131.56	742.4	8,070,000	246.6	924.8	355.2	1,516.4	9,534,000
Average	0.1	50.8	11.0	61.9	673,000	19.7	77.1	29.5	126.4	795,000
1904										
January		52.1	1.4	56.5	614,000	24.6	80.3	12.2	117.2	738,000
February		55.1	20.9	76.3	829,000	25.9	83.6	49.7	159.2	1,001,000
March		52.7	6.4	59.0	641,000	21.7	86.9	22.3	129.9	817,000
April		55.0	8.0	63.0	684,000	15.0	83.2	15.6	114.4	719,000
May		54.1	1.1	58.3	633,000	16.2	79.6	9.3	105.0	660,000
June		51.8	1.2	55.0	598,000	21.0	77.5	8.6	107.6	676,000
July	1.0	47.6		49.4	537,000	20.2	74.4	3.0	103.6	652,000
August	0.8	54.1	5.8	61.2	660,000	23.0	78.1	26.5	128.2	806,000
September		55.4	2.0	58.2	631,000	24.0	80.1	19.2	124.1	781,000
October	0	49.6	0.1	53.0	576,000	25.8	78.1	10.5	113.3	713,000
November	2.2	49.2	0.1	51.6	561,000	23.9	79.3	3.6	106.8	672,000
December	4.0	48.9		53.7	584,000	27.4	79.8	1.4	108.5	682,000
Total	12.8	629.2	53.2	695.2	7,554,000	277.3	959.6	180.7	1,417.6	8,917,000
Average	1.1	52.4	4.4	57.9	629,000	23.1	80.0	15.1	118.1	743,000

TABLE 6 (*Concluded*)

Month	Rainfall in Inches Depth at Hempstead Storage Reservoir	Average Monthly Yield of Old Watershed (67 Square Miles) in Million Gallons per Day not Including Ground-Water Waste: Ground-water delivered to conduit	Surface-water entering conduits	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of Old Watershed per Day per Square Mile in Gallons	Average Monthly Yield of New Watershed (92 Square Miles) in Million Gallons per Day not Including Ground-Water Waste: Ground-water delivered to conduit	Surface-water entering conduit	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of New Watershed per Day per Square Mile in Gallons	Total Yield of Ridgewood Watershed in Million Gallons per Day (159 Square Miles) not Including Ground-Water Waste: Ground-water delivered to conduit	Surface-water entering conduit	Surface-water wasted at supply ponds	Total yield including surface waste	Average Yield of Ridgewood Watershed per Day per Square Mile in Gallons
1905																
January	2.20	23.1	31.8	10.8	65.7	980,000	3.0	57.2	3.6	63.8	690,000	26.1	89.0	14.0	129.5	820,000
February	3.00	24.3	38.2	4.5	66.9	1,000,000	0.4	58.8	1.7	60.9	660,000	24.7	97.0	6.2	127.8	800,000
March	4.05	23.4	35.1	11.2	69.6	1,040,000	....	58.8	4.0	62.9	680,000	23.4	93.9	15.2	132.5	830,000
April	3.18	19.1	33.7	6.8	59.6	880,000	....	58.3	8.6	66.9	730,000	19.1	92.0	15.4	126.5	800,000
May	1.07	22.4	32.2	2.2	56.8	850,000	1.8	54.1	....	55.8	610,000	24.2	86.3	2.2	112.6	710,000
June	3.41	25.1	37.2	0.1	62.5	930,000	6.7	41.8	....	48.4	530,000	31.8	79.0	0.1	110.9	700,000
July	2.33	22.9	43.5	......	66.4	990,000	15.1	30.6	....	45.6	500,000	38.0	74.1	....	112.0	700,000
August	4.54	27.4	30.5	0.2	58.1	870,000	23.5	26.3	....	49.9	540,000	50.9	56.9	0.2	108.0	680,000
September	4.51	27.8	25.5	1.9	55.3	830,000	21.5	29.6	....	51.0	550,000	49.3	55.1	1.9	106.3	670,000
October	2.86	28.4	29.8	0.6	58.8	880,000	25.8	23.3	....	49.2	530,000	54.2	53.1	0.6	108.0	680,000
November	1.81	28.9	28.0	....	56.9	850,000	25.5	21.1	....	46.7	510,000	54.4	49.1	....	103.6	650,000
December	3.86	29.9	30.4	0.1	60.5	900,000	25.5	28.1	....	53.6	580,000	55.4	58.5	0.1	114.1	720,000
Totals	**36.82**	**302.7**	**395.0**	**38.4**	**737.1**	**11,000,000**	**148.8**	**488.0**	**17.9**	**654.7**	**7,110,000**	**451.5**	**884.0**	**55.3**	**1,891.8**	**8,760,000**
Average	**3.07**	**25.2**	**33.0**	**3.2**	**61.4**	**920,000**	**12.4**	**40.7**	**1.5**	**54.6**	**590,000**	**37.6**	**73.7**	**4.7**	**116.0**	**730,000**
1906																
January	4.29	29.6	16.7	3.2	49.5	740,000	31.8	29.7	0.1	61.6	670,000	61.4	46.4	3.3	111.1	700,000
February	1.95	31.2	18.1	3.0	52.4	770,000	32.3	30.9	....	63.2	680,000	63.5	49.0	3.0	115.6	730,000
March	4.98	30.8	16.8	6.4	54.0	810,000	25.4	41.2	0.4	67.0	730,000	56.2	58.0	6.8	121.0	760,000
April	4.56	26.7	24.3	13.3	64.3	960,000	17.6	45.2	3.2	66.0	720,000	44.3	69.5	16.5	130.3	820,000
May	3.41	31.5	22.6	6.7	60.8	910,000	18.5	42.6	0.2	61.3	670,000	50.0	65.2	6.9	122.1	770,000
June	4.26	35.8	26.0	0.8	62.6	930,000	29.9	28.2	....	58.0	630,000	65.7	54.2	0.8	120.6	760,000
July	5.60	35.7	18.9	3.9	58.5	880,000	32.2	29.4	0.8	62.5	670,000	67.9	48.3	4.7	121.0	760,000
August	2.54	39.6	20.9	1.1	61.6	920,000	35.8	19.6	8.9	64.3	700,000	75.4	40.5	10.0	125.9	790,000
September	1.45	41.2	26.7	....	67.9	1,010,000	38.9	13.2	2.9	55.1	600,000	80.1	39.9	2.9	123.0	770,000
October	5.97	40.0	15.4	1.3	56.6	840,000	40.6	14.8	0.5	55.8	610,000	80.6	30.2	1.8	112.4	710,000
November	1.46	40.2	6.2	0.6	47.0	700,000	43.5	14.7	....	58.2	630,000	83.7	20.9	0.6	105.2	660,000
December	3.65	43.4	12.0	1.1	56.5	850,000	42.0	12.4	....	54.4	590,000	85.4	24.4	1.1	110.9	700,000
Totals	**44.12**	**425.7**	**224.6**	**41.4**	**691.7**	**10,320,000**	**388.5**	**321.9**	**17.0**	**727.4**	**7,900,000**	**814.2**	**546.5**	**58.4**	**1,419.1**	**8,930,000**
Average	**3.58**	**35.5**	**18.7**	**3.4**	**57.6**	**860,000**	**32.4**	**25.8**	**1.4**	**60.6**	**650,000**	**57.9**	**45.5**	**4.8**	**118.2**	**740,000**
1907																
January	3.29	41.0	12.2	1.6	54.8	820,000	39.1	26.8	....	65.9	720,000	80.1	39.0	1.6	120.7	760,000
February	1.77	41.4	13.8	1.0	56.2	840,000	38.6	28.2	....	66.9	730,000	80.0	42.0	1.0	123.1	780,000
March	3.27	41.0	13.4	6.0	60.4	900,000	30.7	36.9	1.2	68.8	750,000	71.7	50.3	7.2	129.2	810,000
April	3.67	37.9	13.2	7.3	58.4	870,000	19.8	46.4	0.6	66.7	730,000	57.7	59.6	7.9	125.1	790,000
May	5.11	41.3	16.3	6.5	64.1	960,000	17.0	47.2	1.4	65.6	710,000	58.3	63.5	7.8	129.7	820,000
June	5.93	42.0	12.5	4.5	59.0	880,000	15.5	52.8	0.9	69.2	750,000	57.5	65.3	5.4	128.2	810,000
July	1.65	46.7	12.6	1.1	60.4	900,000	25.8	37.4	....	63.2	690,000	72.5	50.0	1.1	123.6	780,000
August	2.72	26.1	16.5	0.1	62.7	940,000	39.8	20.8	....	60.6	660,000	85.9	37.3	0.1	123.3	770,000
September	8.32	53.6	11.3	1.1	66.0	990,000	39.5	18.2	....	57.7	630,000	93.1	29.5	1.1	123.7	780,000
October	4.10	43.0	12.8	3.0	58.8	880,000	40.5	22.4	....	62.9	680,000	83.5	35.2	3.0	121.7	760,000
November	5.28	46.1	11.3	4.8	62.2	930,000	27.2	33.6	1.0	61.8	670,000	73.3	44.9	5.9	124.0	780,000
December	4.12	39.9	19.5	10.1	69.5	1,040,000	9.6	49.5	0.2	59.3	640,000	49.5	69.0	10.3	128.8	810,000
Totals	**49.23**	**520.0**	**155.4**	**47.1**	**732.5**	**10,950,000**	**343.1**	**420.2**	**5.3**	**768.5**	**8,350,000**	**853.1**	**585.5**	**52.4**	**1,501.1**	**9,450,000**
Average	**4.1**	**43.3**	**13.8**	**3.9**	**51.0**	**910,000**	**28.5**	**35.0**	**0.4**	**64.0**	**590,000**	**71.9**	**48.8**	**4.4**	**125.1**	**790,000**

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

the evaporation losses and the demands of vegetation are doubtless smaller where there is the smaller area of cultivated lands and less vegetation.

In Table 6 preceding, is shown the total yield of the old and the new watersheds of the Ridgewood system for each month, from January, 1897, when accurate records of the amount of waste over spillways of storage ponds were first made, to December, 1907, inclusive. The data from which this table was made up were obtained from the records in the Brooklyn office of the Department of Water Supply.

The amount of waste of surface-water over the spillways of the supply ponds is included in the total estimate of yield, but the large waste of ground-water which occurred in undeveloped portions of the watershed, and which took place at the ground-water collecting works when they were not in operation, are not estimated and can only be roughly approximated.

From the total yield of each watershed, the average annual yield per square mile has been computed on the basis of the ground-water catchment areas that are shown on the map of western Long Island, Sheet 1, Acc. 5530.

As already stated on pages 60 and 61 of this report, these Ridgewood catchment areas include a zone south of the driven-well pumping-stations and infiltration galleries of this system that would be made tributary to the system by the inflection of the ground-water surface towards the wells by the greatest safe development of the ground-water along the entire line of the Ridgewood collecting works. The ground-waters on portions of this line from Forest stream to the Agawam driven-well station are not yet developed, and only during the last four or five years has the ground-water flow on other parts of the line been intercepted.

The total yield of the Ridgewood system is computed from the displacement of the pumps at the Ridgewood pumping-station, corrected for the most part by occasional comparisons with Venturi meters, pitot tube and weir measurements. The error in these quantities probably ranges from 5 to 10 per cent., being much of the time well within the smaller figure.

In the last column of Table 6 is given the estimated total yield of the entire Ridgewood watershed for each year, including the total run-off of both the surface-water and the ground-water.

The above yields of the Ridgewood system are shown

graphically on Sheet 7, Acc. L J 148, which brings out clearly the results of the above tabulation. This diagram is fully explained in the notes accompanying it.

The increase in the yield of the Ridgewood system during the past five years is due to the more complete development of the ground-waters, and a saving of a portion of the underflow that formerly went to waste in the south shore bays. Notwithstanding the fact that the ground-waters of the Ridgewood system are not entirely developed, the present yield of the "old watershed," as shown on this diagram, is about 900,000 gallons per day per square mile, and that of the "new watershed," which is less completely developed, about 700,000 gallons per day per square mile, an average for the whole Ridgewood catchment area of nearly 800,000 gallons per day per square mile.

By constructing additional ground-water works and completely developing the entire watershed, it is believed that the total yield in normal rainfall years may be safely increased to 155 million gallons per day, which is nearly 1,000,000 gallons per day per square mile from the entire ground-water catchment of 159 square miles. This yield is equivalent to 21 inches depth per year, and is nearly 45 per cent. of the average annual rainfall of 44 inches. During long periods of deficient rainfall the total catchment area of the Ridgewood system even when completely developed, would not yield as much as the above figure, because the collecting works are not located nor designed to draw sufficient ground-water storage. The minimum yield would not probably exceed 140 million gallons per day, or 900,000 gallons per day per square mile, and during a long period of deficient rainfall it might readily be 15 or 20 per cent. less than this.

No attempt has been made to correct the yields of the Ridgewood system for the amount of water added to or drawn from the ground-water storage in the pore spaces of the water bearing gravels. As shown in Table 1, page 63, the ground-water works are not generally operated continuously, but are shut down one to two months or more during the wet months of the year, when the flow of the surface streams is large. These intervals each year during the months when the percolation to the water bearing strata is greatest allow the ground-water reservoirs to fill up for the next summer's draft.

The size of the reservoirs that the Ridgewood works are able to draw upon is not large, however. Neither the driven-well stations nor the infiltration galleries can lower the ground-water surface in their immediate vicinity much more than 10 feet, and this depression about the driven-well stations, which in some instances are a mile apart, and from which most of the ground-water supply is obtained, decreases rapidly with the distance from the groups of wells in all directions, so that with the intermittent operation of these stations the average lowering of the water-table over the gathering ground is small (See pages 288 and 289.)

Some ground-water observations in the spring of 1907 in the westerly portion of the Ridgewood system, when compared with the survey of 1903 of the Burr-Hering-Freeman Commission, indicate an average lowering of about two feet over an area of about 35 square miles of the old watershed, from which a ground-water supply of about 30 million gallons has been drawn daily. While some of this difference in the elevation of the water-table was due to the operation of the ground-water works, the greater portion was the result of the smaller rainfall in 1904 and 1905. Continuous observations of the normal ground-water surface at Millburn reservoir, not far from the south shore, showed that during this period the water-table had dropped about two feet. Whatever the cause of the lower level of the water-table over the 35 square miles of the old watershed, the difference meant a total loss of ground-water storage, supposing the sands yield 30 per cent. of their volume of 4380 million gallons, which corresponds to an average draft of three million gallons per day, or 15 per cent. of the average supply. The large rainfall of 1907, however, raised the normal ground-water very nearly to the level of 1903, as shown by the Millburn Reservoir observations and by a few measurements in the old watershed this spring. The abstraction of the ground-water by the works of the Ridgewood system has not, therefore, prevented the recovery of the ground-water reservoirs on their gathering grounds.

The amount of fresh-water storage that has been drawn from the deep water bearing strata through the inshore movement of the salt water since the driven-well systems of the Ridgewood system were operated, cannot be estimated accurately, but it is not probably as much as the amount of surface

storage. In the first place, there is no evidence that the advancing sea-water entirely replaces the fresh ground-water in the interstices of the sands and gravels; rather it appears that the salt water is greatly diluted as it approaches the wells, and replaces only a small portion of the fresh water. For example, the highest chlorine in the Shetucket deep wells, the most seriously affected station, was 500 parts per million, which is only three per cent. of the amount of chlorine in normal sea-water.

The evidence does not furthermore point to more than a limited movement of sea-water in a narrow width toward the center of the cones of depression about each station, because the water-table has not been sensibly depressed at points midway between the stations, and the seaward motion of this water must prevent the encroachment of the salt water between the stations and greatly dilute the salt water approaching the wells, thus minimizing the amount of fresh water replaced by salt.

The rate of advance of the salt water toward the ground-water works of the Ridgewood system was doubtless greatest during the years of low rainfall, but a recession must have taken place during the years of high rainfall, so that, on the average, the amount of fresh-water storage replaced by salt water was small. The Spring Creek station was in operation 14 years before it was seriously affected by sea-water, and then the water contained only 300 parts per million of chlorine at the maximum. Other driven-well stations have been in service quite as long without being affected by salt water at all, and some are equally near the shore. To show how small the storage drawn at Spring Creek from the deep strata must have been, the following computation is made on the probable advance of the sea-water at Spring Creek. This station is only 1500 feet from salt water in the creek below. Suppose that the salt water in the gravels below was originally 3000 feet away, and moved inland on the average during 14 years 214 feet each year, and that in the length of line tributary to this station, which may be assumed to be a mile, the salt water replaced each year 10 per cent. of the pore space, or three per cent. of the volume of the sands in a length of 2000 feet and a depth of 100 feet. The amount of fresh water abstracted was then 2000 x 210 x 100 x .03 x 7.48 = 9,420,000 gallons, or an average for the year of 26,000 gallons per day, which is about 0.5 per cent. of the yield of the station.

The proportion of surface-water in the Ridgewood supply has decreased materially during recent years as a result of the increasing number of ground-water works and the greater volume of ground-water pumped. Ten years ago 60 to 70 per cent. of the whole visible yield of the Ridgewood system (including surface, but not ground-water waste) was surface-water. During the last two years but little more than 40 per cent. of the yield has been accounted for in surface-water at the intakes of the supply ponds and in the surface waste over the spillways.

Judging from the surface run-off of the "new watershed" when little or no ground-water was drawn, the streams have an average natural flow in years of normal rainfall of about 40 million gallons per day, which corresponds to a yield per square mile of the ground-water catchment area of roughly 450,000 gallons per day. The natural surface flow of the streams in the southern Long Island watersheds may therefore be considered to represent about one-half of the total available yield of the entire ground-water catchment area.

Comparison with Watersheds of Surface Supplies

The yield of the Long Island watersheds should not be compared with the delivery of the catchment areas of the large surface-water supplies in this vicinity, without taking into consideration the dissimilarity in the character of the surface soils and substrata and the resulting difference in the uniformity of the run-off.

The surface of the Croton watershed, for example, is underlaid by almost impervious hard pan, and there is practically no ground-water storage. The Long Island watersheds, on the other hand, have loose, porous soils, overlying strata of pervious sands and gravels. Perhaps not more than one-half of the entire yield naturally appears in the surface streams, and the minimum flow seldom drops below 50 per cent. of the average because of the large ground-water storage.

Floods of 20 or 25 times the average volume of run-off, which have occurred on the Croton watershed, are unknown on Long Island. The greatest discharge of one of the largest of Long Island streams in the past two winters, with frozen ground, was only three times the ordinary summer flow, and this lasted only a few hours. Even with the small amount of storage in the shallow supply ponds on the new watershed of

the Brooklyn works between Massapequa and Millburn, only 1.3 per cent. of the rainfall was wasted over the spillways in the last two years.

The average run-off from the Croton watershed during the last 40 years, has been about 24 inches in depth, which is something over 1,000,000 gallons per day per square mile, or about 50 per cent. of the average rainfall. It is estimated on the completion of the Croton Falls reservoir when the storage volume will amount to 290 million gallons per square mile, that an average supply of 336 million gallons per day or 930,000 gallons per day per square mile can be drawn during a long period of low rainfall, and 1,000,000 gallons per day per square mile during normal rainfall years. If an ample volume of storage could be made available on the Suffolk County watersheds, without doubt a larger proportion of the rainfall here should be obtained.

Comparison with Other Ground-Water Catchment Areas

There is no area in the eastern part of this country similar to Long Island, where the ground-water has been developed to such an extent as to afford a comparison with the yield of the Long Island watersheds. In our southwestern states, deep water bearing strata of sand and gravel exist, and have been extensively developed to supply water for irrigation, but little has been done there to determine the yield from a given watershed area, and the climatic conditions, the distribution of the rainfall, the temperature and the amount of evaporation differ so much from those on the Atlantic coast, that the yields, if known, would afford no basis for estimating the supply from the Long Island sources.

The conditions that most clearly resemble those on Long Island are found in northern Europe, although the rainfall is much smaller there, except in the more mountainous regions. Many of the large cities in Germany, Holland and Belgium are supplied with ground-water developed in the deep sands and gravel of glacial and alluvial origin, and these supplies have been investigated with much care.

Estimates of the ground-water yields have been made in Germany, on the basis of collecting 50 per cent. of the rainfall, and the percentages secured on some of the existing works approach these figures.

In 1904, the writer had the good fortune to study many of these European ground-water supplies, and the results of the studies of yield are presented here. Uncertainties exist in the rainfalls and watershed areas of several of the supplies, but not enough to affect the general conclusions that may be drawn from them.

MUNICH

At Munich some interesting data were secured on the yield of the deep galleries of the municipal water works in the Mangfall valley about 30 miles south of Munich. The watershed tributary to the works is a flat table-land, covered with a thick brown soil which overlies deep strata of coarse sand and gravel. Perhaps 30 per cent. of the watershed is wooded; the remainder is for the most part grass land, and a small part is under cultivation near two or three small hamlets. Ordinarily, there is no appreciable surface run-off. The seepage in this watershed is collected in galleries in the Mangfall valley near Muhlthal and Götzing. The ground-water flow is intercepted over an impervious clay floor near its emergence in the valley at a depth of 100 feet or more below the surface of the watershed.

The area of the catchment above the Muhlthal galleries as given by the Director of the Royal Hydrotechnic Bureau, is 14.7 square miles, but investigations have not been made to establish this area beyond question. The catchment area above the entire system, is given as 26.3 square miles, and the engineers of the water-works state that this is more accurate than the area given for the Muhlthal system.

From the records of the water-works, the yield of the Muhlthal galleries during the 10 years from 1885 to 1894 (at which time the works were extended) averaged 21.31 million gallons per day or 30.42 inches depth per year on the watershed. The average rainfall during these years was 47.10 inches, and from the above yield it appears that on the average, 64.5 per cent. of the precipitation was collected. The largest collection was 70 per cent. in 1893, following a high precipitation of 54 inches during the previous year.

Some of the engineers of the water-works believed that perhaps a portion of the flow in the Muhlthal galleries came from the area tributary to the Götzing system, but the yield from the whole watershed tributary to both the Muhlthal and the Götzing galleries appears to be quite as high as from the

Muhlthal galleries alone. The extremely high yields must, however, be accepted with considerable reserve.

AMSTERDAM

The water-supply of Amsterdam is in part obtained from the dunes along the North sea, near Haarlem and Zandvoort. Deep canals were excavated there in the fine white beach sand. Except for a very few trees and some coarse grasses and heather, no vegetation exists on the catchment area. The dunes are comparatively level and the surface run-off is negligible. On the whole, the surface of the dunes is more favorable than that of southern Long Island for a large ground-water yield.

The limit of the catchment area tributary to the canal system, has been very carefully determined, and extensive studies of the movements of the ground-water have been made, so that with a climate and watershed surface analogous to conditions on Long Island, the yields of the dunes furnish perhaps the best comparison with the delivery of Long Island sources. The greater rainfall on Long Island should give a larger percentage of ground-water yield, all other conditions being equal.

The ground-water catchment area in the dunes varies with the rainfall, and the general level of the water-table from 10.4 square miles to 12.3 square miles; the average is 11.6 square miles. During the 14 years from 1889 to 1903 inclusive, this area furnished an average supply of 6.12 million gallons per day which is equivalent to a depth of 11.1 inches on the watershed.

It was believed that this was about all that the watershed would supply, until I. M. K. Pennink, Director of the Municipal Water Supply, showed that some water was being lost through the clay floor underlying the upper water bearing sands. (See transactions, American Society of Civil Engineers, Volume LIV, Part D, page 169, or Transactions of Royal (Dutch) Institute of Engineers, February 1, 1904.) Pennink estimated this loss amounted to three or four million cubic meters per year, which is equivalent to 2.2 to 2.9 million gallons per day. He planned after the completion of his investigations, to draw down the water-table in the dunes to prevent some of the percolation through the clay floor, and has already driven wells beneath the clay to obtain at times, the stored water there. The average supply obtained in 1904 was eight million gallons per day.

From the estimates of Pennink, the catchment area of 11.6 square miles should furnish, if completely developed, more than the present supply of 8.0 million gallons per day, or say from 8.3 to 9.0 million gallons per day. This corresponds to a depth on the average area of watershed of 15.0 to 16.2 inches per year.

The average rainfall from gages maintained on the watershed may be estimated at 24 inches depth. On the basis of the yield from 1889 to 1903, of 11.1 inches depth per year, the watershed yielded $\frac{11.1}{24} = 46$ per cent.

THE HAGUE

The supply of The Hague comes from a development of the dune waters similar to that of Amsterdam. An average supply of 5.1 million gallons per day is collected in filtration galleries from a watershed of 7.0 square miles. This yield corresponds to a depth of 15.3 inches on the watershed, which agrees very well with that obtained from the Amsterdam watershed. No investigations have been made at The Hague, as far as has been learned, to discover any loss through seepage, as on the Amsterdam works.

TILBURG

The small industrial town of Tilburg, in the southeastern part of Holland, is supplied by ground-water from a small driven-well system near the town. The watershed is a barren area covered here and there with patches of thin soil on which grow low grass and heather and a few stunted pines and firs.

Halbertsma, formerly of The Hague, designed these works and laid out the driven-well system for collecting 49 per cent. of the rainfall. The works are now delivering two million gallons per day from the ground-water catchment, the area of which was found to be 3.32 square miles. This corresponds to 12.5 inches depth on the area.

With the rainfall of 27.6 inches, the development now yields $\frac{12.5}{27.6} = 45$ per cent. of the total precipitation.

This yield should not, however, be considered the maximum that the watershed will provide. It is planned to develop still more in the watershed, when it is required.

BRUSSELS

An example of the yield of ground-water sources, to which the rain percolates through more or less impervious strata, is found at Brussels. The city proper is supplied with water from deep galleries in the Forêt de Soignes and the Vallée du Hain. These galleries were driven on a slight grade 20 to 25 feet below the original surface of the ground-water, and 100 to 150 feet below the surface of the ground.

The surface of the Forêt de Soignes is covered with a good sod, and large trees and ponds give evidence of the impervious character of the subsoil. The substrata is said to contain a great deal of clay. The surface topography is favorable to a large run-off. From an excellent ground-water contour map, prepared by the water-works, the catchment area tributary to the galleries is found to be 4.6 square miles.

The average yield of the galleries is 2.1 million gallons per day, or 9.7 inches depth on the catchment area. This is 35 per cent. of the mean rainfall of 27.6 inches.

The sources in the Vallée du Hain furnish 4.8 million gallons per day from an underground watershed that has an area of 16.6 square miles, according to the ground-water contour map. This delivery is only 6.0 inches depth on the watershed, or 22 per cent. of the rainfall. Since the suburbs of Brussels, a few years ago, sought an independent supply from the mountains, the city works have not been drawn upon to their full capacity. Probably the sources du Hain would furnish more than here stated. The surface is highly cultivated and for the most part without trees.

The yields from these European watersheds are summarized in Table 7, following, together with the present delivery of the Ridgewood system of the Brooklyn works, and the estimated safe yield of the Suffolk County catchment areas.

Comparing the conditions here with those abroad, noting that the air temperatures on which the evaporation losses largely depend are nearly the same and that the character of the surface of the Suffolk County catchment areas are as favorable for a large percolation as many of those abroad, it would appear reasonable to expect here fully as large a percentage yield, perhaps 900,000 or even 1,000,000 gallons per day per square mile if sufficient storage could be developed in the pore spaces of the water bearing strata to sustain this yield during periods of low precipitation. The European ground-

TABLE 7

COMPARISON OF YIELDS OF LONG ISLAND SOURCES WITH YIELDS OF VARIOUS EUROPEAN GROUND WATER WORKS

City	Location of Source of Supply	Characteristics of the Surface and the substrata of the watershed that affect the yield of the ground water sources	Average El of Watershed above Sea Level Feet	Area of Ground Water Catchment in Square Miles	Average Annual Temperature of Air Fahrenheit	Period of Observation on Rainfall and Ground Water Yield	Average Rainfall on Watershed in Inches	Average Yield of Watershed: Total per Day in Mil. Gals.	Average Yield of Watershed: Inches Depth per Year	Average Yield of Watershed: Gallons per Day per Square Mile	Average Yield of Watershed: Percentage of Average Rainfall
		LOOSE POROUS SOILS AND SUBSTRATA									
Munich, Bavaria	Muhlthal	Nearly level table land: but little run-off. 30% wooded, remaindergrass land and in cultivation. Surface covered with thick brown loam overlying coarse sands and gravels	2000	14.7 Approx	45.2	1885-94	47.1	21.3 (Approximate)	30.4 (Approximate)	1450 000 (Approximate)	65.
Amsterdam, Holland	Dunes near Harlem	Approximately level dunes. No appreciable surface run-off. Upper strata fine white beach sand that supports scanty cover of coarse grass and heather.	30	11.6	49.5	1889-1903 Safe Maximum	27.0	6.1 8.3	11.1 15.0	530 000 710 000	41. 56.
The Hague,	Dunes near Scheveningen	Same as the Amsterdam Dunes	30	7.0	49.5	—	27.0	5.1	15.3	730 000	57.
Tilburg, Holland	Near Tilburg	Barren heath covered with patches of thin soil, bearing coarse shrubs and herbage and a few stunted pines and firs.	50	3.3	50.	1903	27.6	2.0	12.5	600 000	45.*
		COMPACT IMPERVIOUS SOILS AND SUBSTRATA									
Brussels, Belgium	Foret de Soignes	Park with green grass, large trees and ponds. Soil is rich and subsoil and underlying strata somewhat impervious, with clay beds. Topography favorable to surface run-off.	300	4.6	51.0	—	27.6	2.1	9.7	460 000	35.
	Vallée du Hain	Open countryside highly cultivated. Soil and substrata more or less impervious.	400	16.6	51.0	—	27.6	4.8	6.0	290 000	22*
		LONG ISLAND SOURCES									
New York	Ridgewood System in Western Long Island, Old Watershed	Mostly sproutland and thin woods of scrub oak and stunted pine. Soil thin and loose, substrata generally coarse and pervious. But little grass land or sod. Forest litter favorable to maximum percolation and small evaporation. Streams are fed from ground water for a good part of the year. Surface run-off small and only becomes appreciable on rare occasions when ground is frozen deeply.	60	67	51.6	1897-1907	47	60 In 1907.	18.9	900 000	40.*
	New Watershed		90	92	51.6	1897-1907	47	65 In 1907.	14.7	700 000	31.*
Proposed Suffolk County Watershed		Similar to watersheds in Western Long Island but less developement, more pervious and open and more favorable for large collection of ground water.	80	332	51.6	—	Normal 45	265	16.8	800 000†	37.

*These sources are not yet developed to their maximum capacity. †Assumed as safe yield for estimates.

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water works are not designed to secure much storage, and their yields fall below the average given above during years of deficient rainfall.

STORAGE REQUIREMENTS FOR DEVELOPMENT IN SUFFOLK COUNTY OF 800,000 GALLONS PER DAY PER SQUARE MILE

Provisions for adequate storage have seemingly been neglected in the construction of large ground-water works, although such provisions are never omitted in works designed for the development of surface-waters when the draft exceeds the low-water flow of a stream. The reason for this neglect of one of the vital features of good water-works practice in the case of ground-water works has doubtless been the belief of the designers in the inexhaustible character of the ground-water sources, the conviction that the minimum supply was safely in excess of the maximum draft. Such is the case in works of small capacity supplying small communities which represent the majority of ground-water installations but on ground-water works like those of the Ridgewood system and the proposed Suffolk County project, where the draft is nearly equal to the available supply, the problem of ample storage cannot be neglected.

Storage Requirements for Surface-Water Supplies

The delivery of the Long Island catchment areas is so much more uniform than that of the watersheds of surface supplies that the storage requirements for the proposed Suffolk County works should be much less than have been found necessary, for example, on the Croton and Sudbury watersheds for a given unit yield. The volume of storage provided on the Croton and Sudbury watersheds is given below:

	Volume of Storage Reservoirs Million Gallons Per Square Mile	Estimated Safe Yield With This Storage in Million Gallons Per Day in Square Miles	Storage Requirements Estimated by J. R. Freeman in "Report on New York Water Supply" to Provide Daily Yield of 800,000 Gallons Per Square Mile With no Water Surface
Croton (originally)	150	700,000	160
Croton on completion of Croton Falls dam	290	900,000	...
Sudbury	181	700,000	200

On the basis of the storage requirements on the Croton and Sudbury watersheds, it would be necessary for a uniform draft of 800,000 gallons per day per square mile from the proposed Suffolk County works, to provide a storage volume from 160 to 200 million gallons per square mile. The normal rainfall on the Suffolk County watershed is about the same as that on the Sudbury, and the amount of storage based upon the requirements found necessary on this drainage area is perhaps a better basis for estimating the Suffolk County needs than those of the Croton, because the average rainfall on this watershed in the New York uplands is several inches greater than in eastern Long Island. The amount on even the Croton basis of 160 million gallons per square mile is, however, considered an excessive requirement in Suffolk county because the Long Island streams are fed largely by the ground-water inflow from the shallow water-table tributary to them, and the rate of run-off here is consequently so much more uniform than the run-off of the Sudbury or Croton watersheds.

Uniformity of Run-off in Southern Suffolk County

By constructing a mass curve of the flow of 11 of the Suffolk County streams in 1907, which are shown on Sheets 8, 9 and 10, Accs. L 609, L 610 and L 611, it is estimated that a storage of 4,500 million gallons would have equalized the delivery of these streams, which had an average flow of about 100 million gallons per day. Assuming the other streams would have required a proportional amount of storage, all the Suffolk County streams summarized in Table 5, page 113, would have required, say, 7,000 million gallons of storage. This represents a storage of 21 million gallons per square mile on the whole watershed of 332 square miles to maintain a uniform flow of 150 million gallons per day, equivalent to over 450,000 gallons per day per square mile.

The minimum flows of the Suffolk County streams in 1894 (see Table 5, page 113) were, on the whole, less than in 1907, although the estimated total was greater because of a large flow of the Patchogue river recorded in that year. It is possible that much smaller minimum flows may have occurred, if tradition may be accepted, so that during a long period of dry years, a storage much in excess of 21 million gallons per square mile would be needed to maintain, say, a continuous supply of 400,000 gallons per day from the surface streams.

The deep ground-water underflow which makes up fully half of the run-off of the southern Long Island watersheds is much more uniform than the flow of the surface streams, and probably varied but a few per cent. during the year 1907. It was shown in the report of the Burr-Hering Freeman Commission (pages 816-829) that the water-table in the center of the island had not fluctuated more than 12 feet during the last 60 or 70 years. Considering that the hight of the ground-water in the center of the island above sea-level represents the head upon which depends the rate of flow of the ground-waters, the volume of the deep underflow at the south shore has not varied over 20 per cent. in this time.

Probable Storage Requirements in Suffolk County

It is shown on page 290 of this report that the total amount of storage on the Ridgewood watershed does not exceed 30 million gallons per square mile, which has proven inadequate during dry years.

For the proposed Suffolk County works, a storage of 50 million gallons per square mile is probably ample to maintain a yield of 800,000 gallons per day per square mile. Fully half of this should be developed along the main line of the proposed works at the south shore and in the Peconic valley. The remainder can easily be obtained on the branch storage lines proposed for the complete development. Indeed these lines may be made to provide a still greater amount of storage, even to 75 or perhaps 100 million gallons per square mile, if the operation of the works shows this amount necessary.

CONCLUSIONS ON UNIT YIELD

From the above considerations of the present yield from the watersheds of the Ridgewood system in Nassau and Queens counties, the deliveries of other similar catchment areas and the storage volume that may be made available during periods of low rainfall, the safe average yield per square mile of Suffolk County watershed has been taken as 800,000 gallons per day.

This estimate is believed to contain a factor of safety to provide for more severe conditions of drought than have been recorded in the past 40 years. During years of ample rainfall it is believed more than this may be safely collected.

YIELD OF SUFFOLK COUNTY WATERSHEDS

Gross Yield

On the basis of this unit yield of 800,000 gallons per day per square mile, the entire Suffolk County catchment area of 332 square miles would safely yield an average supply of 266 million gallons per day. The several areas of ground-water catchment that would be drawn upon by the four successive extensions of the collecting works from the Nassau County line are tabulated below, together with the probable gross yield of each area.

Stages of Construction in Suffolk County	Section of Suffolk County Collecting Works: From	To	Length of Section in Miles	Area of Ground-Water Catchment in Square Miles	Probable Average Yield of Section Million Gallons per Day	Total Volume Available at this Stage of Construction
	SOUTHERN SUFFOLK COUNTY SOURCES					
1	Nassau county..	Great River ..	14.7	100	80	80
2	Great River.....	South Haven..	14.8	106	85	165
3	South Haven....	Quogue......	18.9	88	71	236
	Total in southern Suffolk county..................		**48.4**	**294**	**236**	...
	PECONIC VALLEY SOURCES					
4	Westhampton...	Riverhead....	5.8	Aqueduct	...	...
	Riverhead......	Calverton....	4.3	38	30	266
	Total of all sources.........		**58.5**	**332**	**266**	

The fifth and last stage of construction would be the building of the three branch lines. No more water would be made available by these lines, except as would be secured from without the watershed by the inflection of the water surface through deep pumping, but these branch lines would make large volumes of stored ground-water available in periods of low rainfall, when the draft on the main south shore works would be decreased through the general lowering of the whole water-table.

Amount of Water to Be Appropriated for New York City

It is shown in a subsequent appendix that the amount of water that is at present required for domestic and industrial uses in Suffolk county outside of that utilized for water-power does not exceed 6 million gallons per day. Probably not over 10 million gallons per day need be lost at any time in maintaining the levels in the ponds near the aqueduct line. This

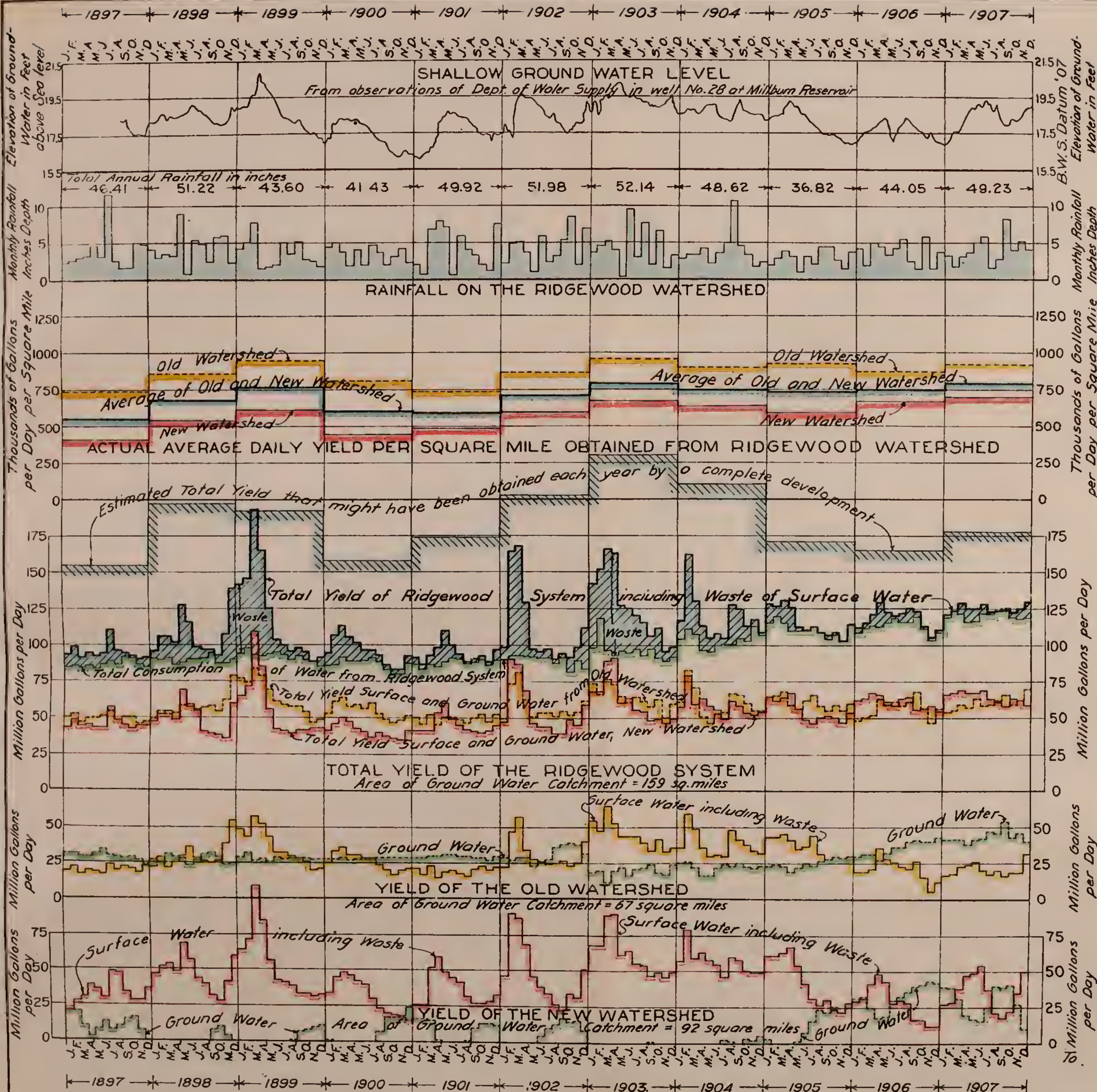
would leave as the net supply that could be appropriated for New York City, without material injury to Suffolk County interests, 250 million gallons per day.

With the probability of a higher unit yield than assumed for these estimates, the needs of a population of 150,000, fifty years hence, could still be supplied without diminishing the supply of 250 million gallons per day for New York City.

This estimate of a net supply of 250 million gallons per day from the Suffolk County sources, is larger than hitherto made. No previous project, however, has contemplated an extension of the works to Quogue and to the Peconic river, as estimated upon in this plan, nor have the branch lines into the center of the island been considered in other projects.

Mr. I. M. de Varona, as Chief Engineer of the Brooklyn Water Works, proposed in 1896 to develop a supply of 100 million gallons per day in Suffolk county. Mr. de Varona planned, however, to go only as far as the Carman's (Connecticut) river, and supplement the flow from the larger streams between this river and Nassau county, by four intermediate driven-well stations along the proposed conduit line near the Montauk division of the Long Island railroad. Most of this supply was to be surface-water; only 20 per cent. was to be pumped at the driven-well stations, to maintain the supply in dry periods.

The Commission on Additional Water Supply estimated in 1903, on the basis of a yield of 800,000 gallons per day, that 175 million gallons could be secured from a ground-water catchment. The data available at the time on the area of catchment was less complete than now, and the watershed east of Moriches and in the Peconic valley was not considered.



The period of operation of the Ridgewood System covered by this diagram, from 1897 to 1907 inclusive was one of high rainfall. In only one year 1905 was the precipitation much below the normal. Complete records of waste over spillways of supply ponds were not kept during the dry years preceeding 1897, and no estimate of the total yield can be made.

The height of ground water shown by the line at the top of this diagram shows the normal level of the watertable undisturbed by pumping near the south shore of Long Island, along the line of the Ridgewood Collecting Works. This level is a measure of amount of ground water available at works.

The average monthly yields of the surface supplies and of the ground water works are shown separately in the curves at the bottom of this diagram for both the old and the new watershed. It should be noted that until 1905 the ground water works in the new watershed were only operated to supplement the surface supplies during the months of low rainfall. The large consumption in the last three years has made it necessary to run the ground water works more continuously.

A general decrease in the yield of the surface supplies corresponding to the increase in ground water pumpage is noticeable on both the old and the new watershed during the last three years.

The total yield of each of the watersheds and the sum of the old and the new are shown in the curves "Total Yield of the Ridgewood System."

The hatched area below the total yield of the system represents the amount of surface water that was wasted over the spillways of the supply ponds in both watersheds. This does not include large volumes of ground water underflow that escape to the sea. The line beneath this hatching gives the actual consumption of the Ridgewood supply in Brooklyn Borough.

In years of normal rainfall the amount of waste is not more than 3 or 4 per cent of the supply and did not exceed this figure in 1907 with rainfall of 49.23 inches. With more conduit capacity, even this small waste might have been reduced. The total conduit capacity exclusive of 72 inch pipe is 125 Mil. Gals. per day.

The curve giving "estimated total yield that might have been obtained by a complete development" assumes the construction of additional stations to obtain entire ground water yield outside of villages of Rockville Center and Freeport. The effect of ground water storage carried over from wet years is here shown.

From this diagram and other estimates it is believed that during a period of normal rainfall years the total safe supply that may be obtained from the Ridgewood system would not exceed 155 Mil. Gals. per day.

The curves of yield per square mile of watershed were computed from the total actual yield of surface and ground water by dividing by the total area of ground water catchment including portions of watershed where ground water is not developed.

These curves show that the new watershed is now yielding about 700 000 gallons per day per square mile, and the old watershed nearly 900 000 gallons per day per square mile. If the ground waters in the Ridgewood watershed should be completely developed the yield per square mile of the whole watershed in normal rainfall years would be nearly 1,000,000 gallons per day.

City of New York
BOARD OF WATER SUPPLY

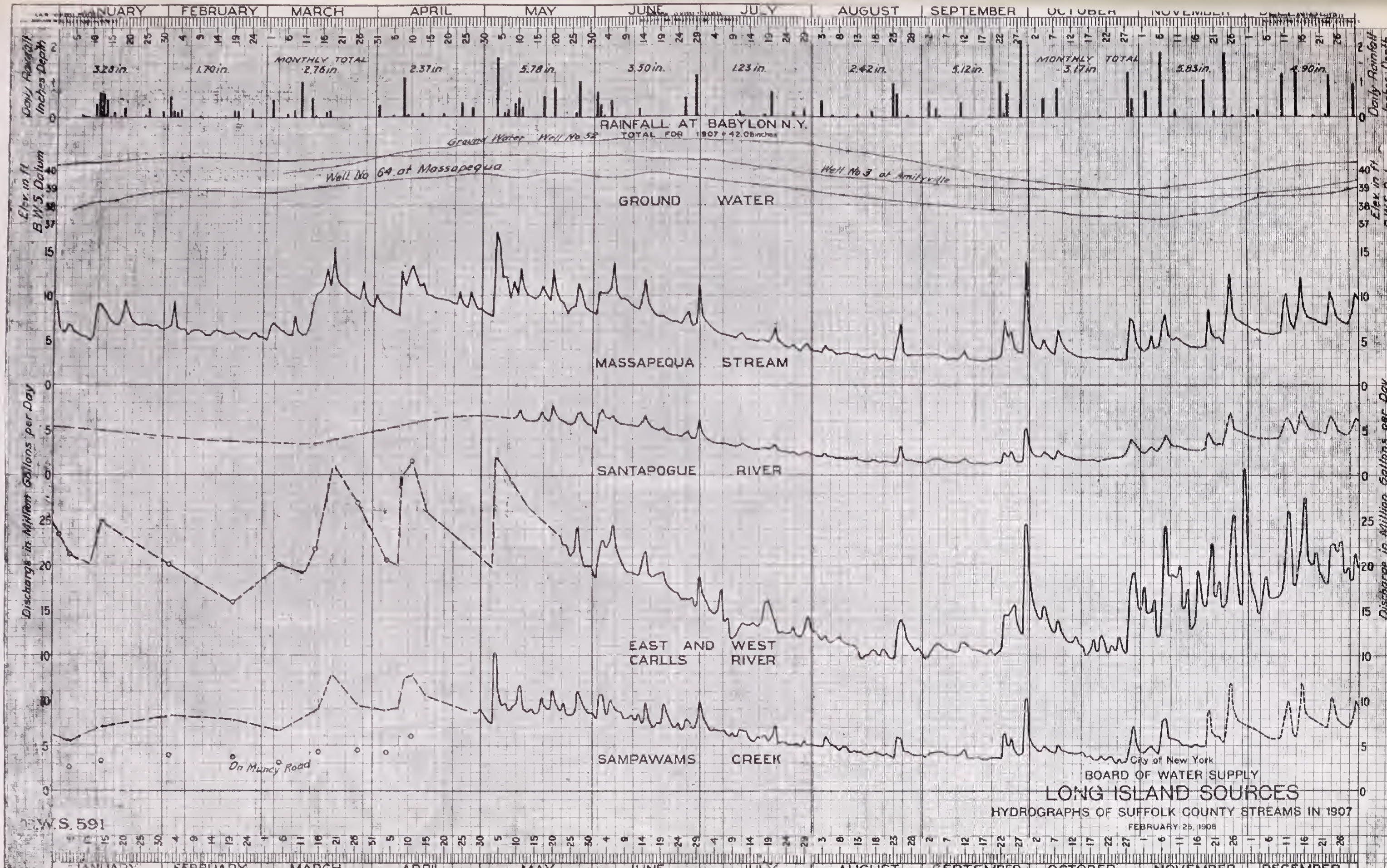
LONG ISLAND SOURCES

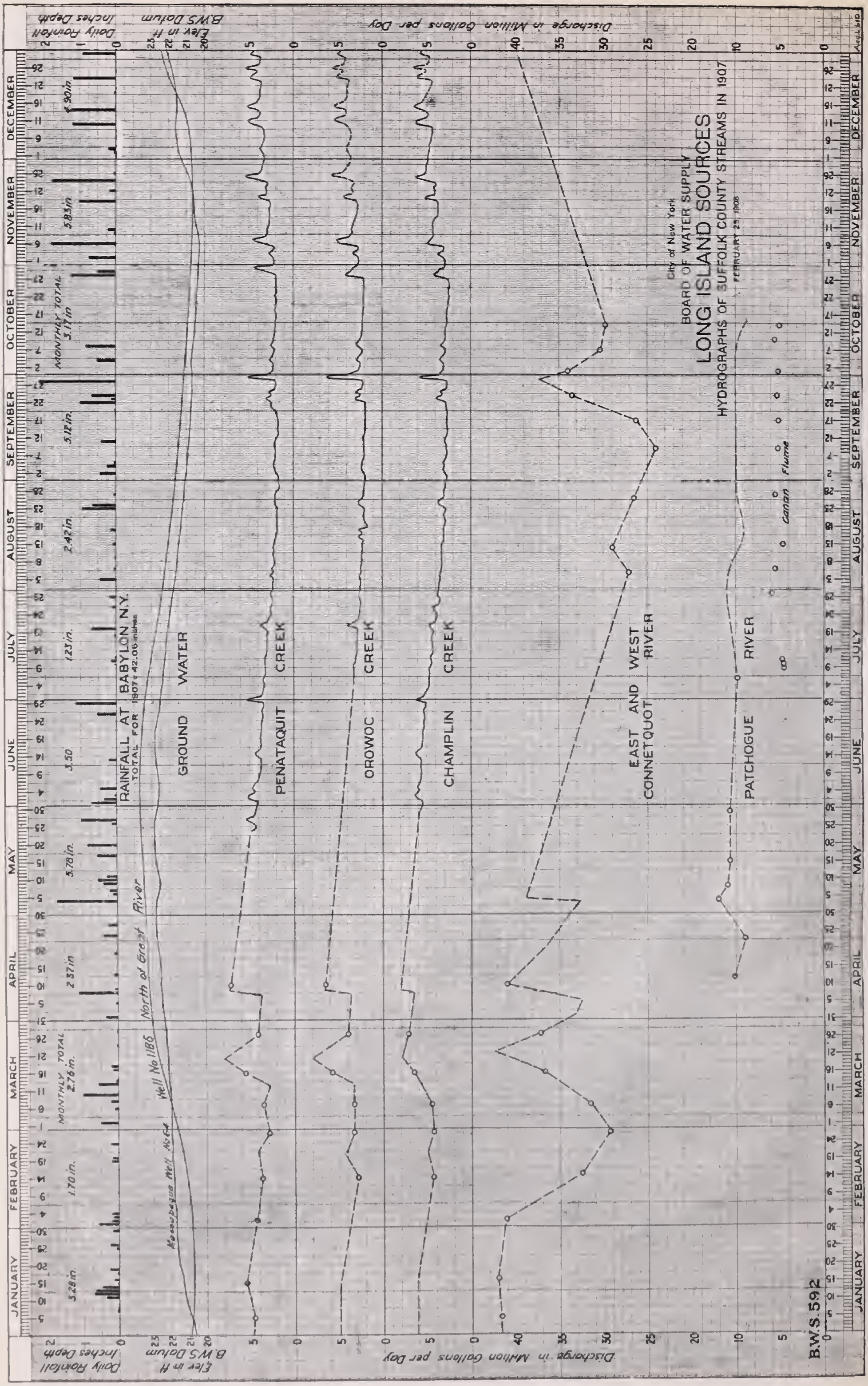
BROOKLYN WATER SUPPLY

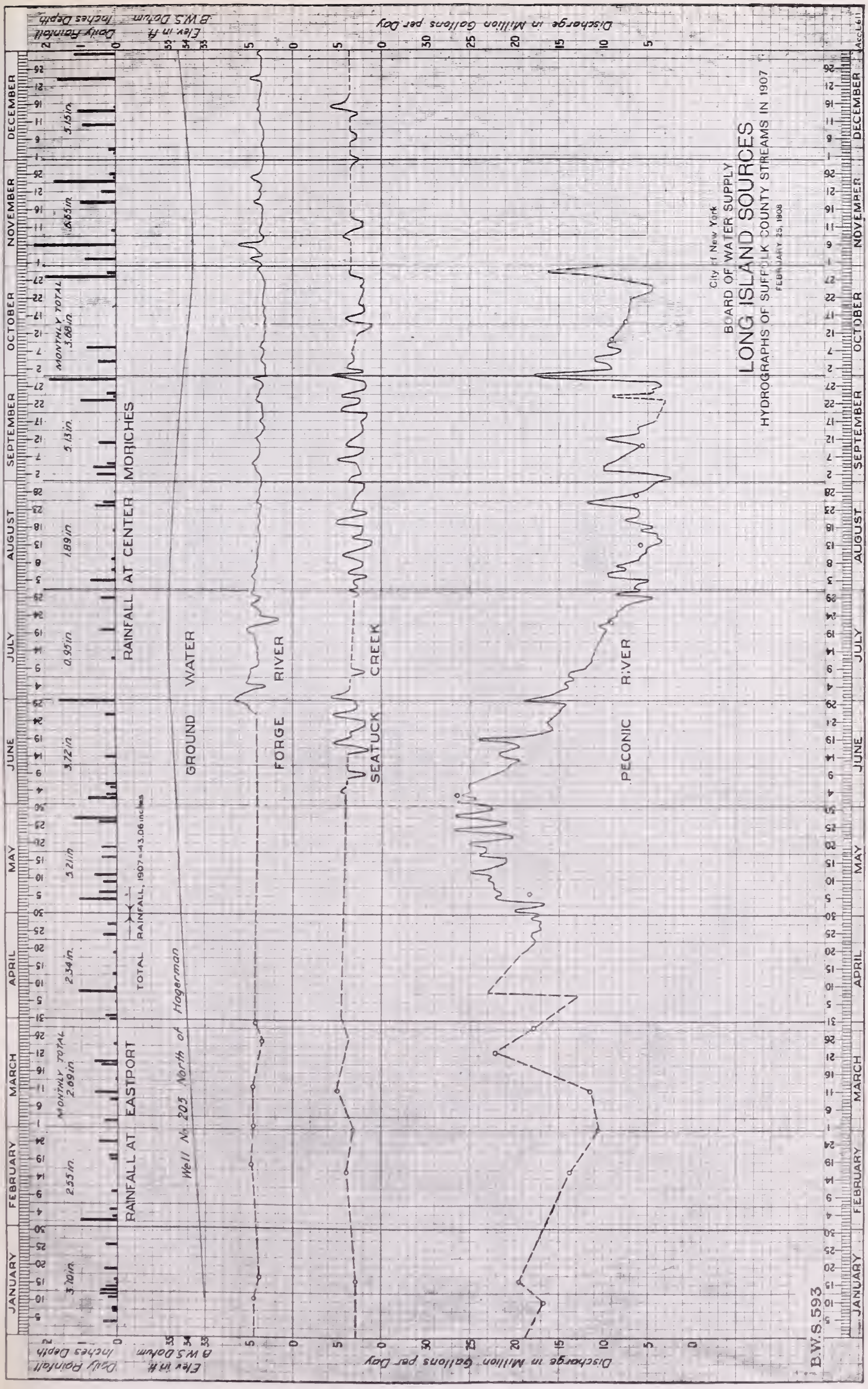
YIELD OF THE RIDGEWOOD SYSTEM

From 1897 to 1907
From Records of the Department of Water Supply
FEBRUARY 25 1908

M. B. BROWN PRINTING & BINDING CO., N. Y.


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
HYDROGRAPHS OF SUFFOLK COUNTY STREAMS IN 1907
FEBRUARY 25, 1908
RAINFALL AT BABYLON N.Y.
TOTAL FOR 1907 = 42.06 inches
Ground Water Well No 52
Well No 64 at Massapequa
Well No 3 at Amityville
GROUND WATER
MASSAPEQUA STREAM
SANTAPOGUE RIVER
EAST AND WEST
CARLLS RIVER
SAMPAWAMS CREEK
On Muncy Road
Daily Rainfall Inches Depth
Elev. in ft. B.W.S. Datum
Discharge in Million Gallons per Day
3.23 in.
1.70 in.
MONTHLY TOTAL 2.76 in.
2.37 in.
5.78 in.
3.50 in.
1.23 in.
2.42 in.
5.12 in.
MONTHLY TOTAL 3.17 in.
5.83 in.
4.90 in.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
W.S. 591


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
HYDROGRAPHS OF SUFFOLK COUNTY STREAMS IN 1907
FEBRUARY 25 1908
B.W.S. 592
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
Daily Rainfall Inches Depth
Elev in ft B.W.S. Datum
Discharge in Million Gallons per Day
RAINFALL AT BABYLON N.Y.
TOTAL FOR 1907 = 42.06 inches
MONTHLY TOTAL
3.28 in.
1.70 in.
2.76 in.
2.37 in.
5.78 in.
3.50
1.23 in.
2.42 in.
5.12 in.
3.17 in.
5.83 in.
4.90 in.
Massapequa Well No. 64
Well No. 1186
North of Great River
GROUND WATER
PENATAQUIT CREEK
OROWOC CREEK
CHAMPLIN CREEK
EAST AND WEST CONNETQUOT RIVER
PATCHOGUE RIVER
Canaan Flume


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
HYDROGRAPHS OF SUFFOLK COUNTY STREAMS IN 1907
FEBRUARY 25, 1908
RAINFALL AT EASTPORT
RAINFALL AT CENTER MORICHES
TOTAL RAINFALL, 1907 = 43.06 inches
Well No. 205 North of Hagerman
GROUND WATER
FORGE RIVER
SEATUCK CREEK
PECONIC RIVER
Daily Rainfall Inches Depth
Elev. in ft. B.W.S. Datum
Discharge in Million Gallons per Day
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
3.70 in.
2.55 in.
MONTHLY TOTAL 2.89 in.
2.34 in.
3.21 in.
3.72 in.
0.95 in.
1.89 in.
5.13 in.
MONTHLY TOTAL 3.68 in.
5.65 in.
5.15 in.
B.W.S. 593

APPENDIX 2

LOCATION OF PROPOSED WORKS IN SOUTHERN SUFFOLK COUNTY, TO AVOID IMPAIRMENT OF THE QUALITY OF SUPPLY AND ANNOYANCE AND DAMAGE TO LOCAL RESIDENTS

BY WALTER E. SPEAR, DIVISION ENGINEER

On first thought, the most natural location for the collecting works in southern Suffolk county might appear to be on a line near the south shore, or the edge of the salt marshes, where the drainage area tributary to the works is a maximum, and where, necessarily, the flow in the surface streams and the volume of the ground-water underflow from the rainfall on the upland watershed is greatest. Further consideration shows, however, that in order to properly safeguard the quality of the proposed water-supply and to avoid unnecessary annoyance and material damage to local residents, a small percentage of the total yield should be sacrificed, and the collecting works located at some distance back from the south shore bays and the larger villages.

QUALITY OF SUFFOLK COUNTY WATERS

In Table 8 on the following page are given the partial analyses of many ground-waters of the Suffolk County watersheds. Four classifications of these waters have been made according to the amount of dissolved mineral matter that they contain.

It will be interesting to state briefly the meaning and the relative importance of these analyses.

Physical Examination

Temperatures are observed when the waters are collected. If observations on ground-waters show temperatures far above or below the average annual air temperature, it is generally evidence of the infiltration of surface-water or the exposure of the water in shallow wells.

TABLE 8

Analyses of Ground-Waters of Suffolk County Watersheds

Parts per Million

	Temperature	Turbidity	Color	Albumenoid Ammonia	Free Ammonia	Nitrite	Nitrate	Total Solids	Chlorine	Hardness	Alkalinity	Iron
NORMAL GROUND-WATERS												
Wyandanch stovepipe well	..	..	6	.014	.006	.002	0.10	25.0	4.0	3.2	1.5	0.25
Lindenhurst stovepipe well	..	15	16	.030	.010	.002	....	33.0	4.1	7.9	6.5	....
Babylon experiment station	..	..	4	.023	.008	.002	0.05	24.0	4.6	5.6	3.3	0.15
Islip stovepipe well	50	..	3	.010	.006	.001	...	24.0	3.9	3.2	3.0	0.20
SUPPLIES OF LOCAL WATER-WORKS												
Amityville water-works	50	..	10	.014	.036	.003	0.65	37.0	5.4	12.7	9.0	....
Babylon water-works	50	1	3	.014	.008	.003	0.80	40.0	5.4	24.7	8.0	0.30
Bayshore water-works	52	..	3	.042	.006	.002	0.18	68.0	4.5	7.9	6.0	0.15
Patchogue water-works	49	..	7	.012	.008	.002	0.15	58.0	12.0	15.6	7.5	0.30
WATERS FROM SMALL DOMESTIC WELLS												
Amityville domestic well	49	5	36	....	....	....	0.1	28.0	6.2	6.3	5.5	0.4
West Babylon domestic well	49	1	10	....	....	....	....	24.0	3.7	15.6	4.5	0.1
Central Islip railroad station	46	3	30	.062	.080	.009	....	43.0	2.9	11.1	7.5	0.70
Holbrook domestic wells	51	4	10	....	....	....	0.35	38.0	5.2	14.8	14.0	0.65
Holbrook domestic well	50	4	5	....	....	....	7.0	190.0	14.9	48.6	7.5	0.8
Great River railroad station	51	3	8	....	....	....	....	29.0	6.2	3.2	2.5	0.90
Oakdale railroad station	52	1	5	.024	.008	.001	0.05	31.0	5.4	3.2	2.5	0.20
Bohemia domestic well	49	2	18	....	....	....	0.10	21.0	3.3	6.3	4.0	0.30
Sayville domestic well	50	2	26	....	....	....	0.30	32.0	4.6	12.7	6.0	0.50
Patchogue domestic well	52	..	9	....	....	....	0.45	44.0	7.5	11.1	10.5	0.30
Bellport domestic well	47	1	6	....	....	....	0.05	34.0	5.4	7.9	6.5	0.1
Brookhaven domestic well	54	3	22	....	....	....	0.05	38.0	6.0	4.8	4.5	0.9
Yaphank domestic well	52	4	8	....	....	....	14.0	89.0	9.5	33.8	5.5	0.40
Yaphank domestic well	52	10	14	....	....	....	20.0	206.0	28.2	44.3	11.0	4.0
Middle Island domestic well	53	10	20	....	....	....	1.3	38.0	6.1	18.2	11.5	12.0
Moriches domestic well	53	..	5	....	....	....	....	37.0	5.4	14.8	12.5	0.3
Center Moriches domestic well	52	2	11	....	....	....	0.18	34.0	6.3	10.3	7.3	0.4
Eastport, L. I., Country Club, dug well	52	1	8	....	....	....	5.0	117.0	12.1	44.2	11.5	0.15
Westhampton domestic wells	52	2	10	....	....	....	0.03	40.0	7.1	12.9	3.8	0.05
Calverton domestic wells	52	2	20	....	....	....	0.70	108.0	11.3	27.3	24.0	3.5
Riverhead domestic wells	53	2	5	....	....	....	50.0	432.0	26.1	97.2	4.0	0.30
Riverhead domestic wells	52	..	7	....	....	....	0.30	25.0	5.6	9.5	4.0	0.70
WATERS FROM OFF-SHORE ISLANDS AND BEACHES												
Muncie Island deep well	..	2	10	.016	.016	.002	....	64.0	13.0	12.7	9.5	0.3
Oak Island Beach well	..	2	22	.064	.010	.002	0.35	118.0	43.1	19.5	6.5	0.5
Fire Island Beach open pit	..	3	15	.060	.008	.003	0.55	120.0	38.1	38.0	8.0	0.9

The determination of turbidity is not important for ground-waters, because such waters are always clear except as there may be some iron in suspension. Turbidities less than three or four on the empirical scale, by which they are measured, are hardly noticeable.

The color of a water is also determined by comparison with empirical standards. A colorless water, as distilled water, has a color of 0 and a color less than 20 or 30 is hardly perceptible. Color results from organic matter or "leaf tea" in solution. Ground-waters are generally colorless, except those drawn near swamps or sources of organic pollution. "Apparent color" in unfiltered ground-waters may result from finely divided particles of iron oxide.

Chemical Examination

The amount of nitrogenous organic matter in a water is ordinarily determined in parts per million as albumenoid ammonia. Free ammonia represents the first products of decomposition, and nitrite and nitrate are the successive steps in the change to the final mineralized condition. Excepting supplies near sources of subsurface pollution, ground-waters contain but little organic matter because it has been entirely oxidized to nitrate in the natural filtration that takes place in passing through the surface soils.

The total solids represent all the organic and mineral contents of the water left after evaporation.

Chlorine, which occurs as common salt, or other chlorides, is found everywhere. If the amount of chlorine is in excess of the normal in any locality it is an index of pollution or evidence of infiltration of sea-water. The normal chlorine on Long Island generally varies from three parts per million in the center of the island, to about six parts near the shores. Outlying bars and the easterly flukes of the island, which are more exposed to the sea breezes, have much higher normals.

Hardness is a measure of the destroying effect of the water on soap. When the hardness is less than 10 it is not noticeable, and waters having a hardness less than 25 are not objectionable. The alkalinity represents that portion of the hardness that is made up of carbonates and bicarbonates. The remainder of the hardness consists of sulphates, nitrates, etc. The

normal ground-waters from the siliceous sands of Long Island are soft. A hardness in these waters much greater than 10 is evidence of sewage, animal wastes or the presence of sea-water.

The occurrence of iron is considered later at some length.

Bacterial and Microscopic Examinations

No bacterial and microscopic examinations of these Suffolk County waters have been made. The work of the Burr-Hering-Freeman Commission showed that deep ground-water in its natural state is sterile. It is unusual, however, to find a ground-water supply without a few organisms and great numbers occur in wells when conditions are favorable for their growth. While these organisms are harmless, from a sanitary point of view, they sometimes give rise to offensive tastes and odors, and fill up the wells and the pipes of the distribution system.

Normal Ground-Waters

The first four samples in Table 8 come from the undeveloped scrub oak lands, and are representative of the normal Suffolk County ground-waters unaffected by pollution from the resident population. These waters are uniformly cool, generally clear, colorless and contain but little organic matter or mineral salts. The amounts of chlorine, which in other localities might be interpreted as evidence of pollution, are normal for watersheds so near the sea, and represent the salts carried inland by moisture-laden ocean winds. The slight hardness of these waters, which has a like origin, is caused, for the most part, by sulphates. Carbonates, of which the sea-salts contain a relatively small proportion, are naturally low, as there is no limestone rock or other calcareous matter on Long Island. The amount of iron in these waters from the yellow, water bearing sands and gravels is not sufficient to give any trouble. Altogether, these natural ground-waters of Suffolk county are most attractive for a public supply, absolutely safe for domestic use and satisfactory for all commercial purposes.

The comparatively high turbidity and color of the water at the Lindenhurst well was due to scale from the well casing.

Supplies of Local Water-Works

The larger public water-supplies which are situated in the outskirts of the south shore villages, are of satisfactory qual-

ity, but they show in the larger amounts of nitrates, chlorine and in greater hardness and alkalinity, the effect of subsurface drainage from the local population. These villages have no general drainage system; where the most primitive methods of sewage disposal are not still in use, the house drains are connected with cesspools and the ground-water in their vicinity is consequently much polluted.

Waters from Small Domestic Wells

Many of the waters from dug and driven wells at farm houses, country residences and railroad stations are as pure as the normal ground-waters first shown in this table. Others taken from wells near points of disposal of sewage and household wastes contain much dissolved mineral matter and are noticeably high in hardness and alkalinity. A bacterial examination would doubtless show these waters to be free from organic life, as a result of their filtration through the substrata of sand and gravel. While they may be perfectly safe to drink, such waters cannot be considered satisfactory for domestic or industrial uses.

Waters from Off-Shore Islands and Beaches

The last three samples in Table 8 are of interest in showing the character of the waters obtained on the small islands and sand beaches that separate the Great South bay from the Atlantic ocean.

The sample from Muncie island was taken from a flowing well 240 feet deep, and exhibits only a slight seepage of sea-water to the stratum in which this water flowed from the main Long Island shore, 3.5 miles away. The water from Oak island was drawn from a shallow well, and that from Fire Island beach from an open pit in the beach sand. Both waters represent rain-water that has fallen upon these islands, and it is not surprising, therefore, that they are high in mineral salts, because of their proximity to the sea. Note, however, the greater amount of chlorides in proportion to the total solids than in the waters of domestic wells polluted by human wastes.

Surface-Waters

The analyses of the surface-waters in Suffolk county are presented in Table 9. These waters represent ground-waters

TABLE 9

Analyses of Suffolk County Surface-Waters

Parts per Million

Source of Sample	Turbidity	Color	Albumenoid Ammonia	Free Ammonia	Nitrites	Nitrates	Chlorine	Hardness	Alkalinity
Santapogue river	1	18	.050	.012	.002	..	6.0	3.5	3.5
Carll's river	0	24	.060	.016	.002	.10	7.0	3.5	3.5
Sampawams creek	1	23	058	.012	.002	.25	6.0	7.0	7.0
West brook	2	15	.062	.198	.010	.50	...	14.5	2.0
Penataquit river	1	16	.068	.038	.003	.30	...	8.5	...
Orowoc creek	0	15	.046	.012	.003	.05	7.0	6.5	6.5
Champlin creek	1	15	.038	.006	.002	.	6.5	6.5	6.5
Connetquot river, West branch	1	9	.026	.036	.002	...	6.5	14.5	14.5
Connetquot river, East branch	0	15	.026	.010	.003	...	6.0	12.5	12.5
Brown's river, West branch	0	12	.032	.010	.002	.15	6.0	6.5	6 5
Tuthill creek	0	10	.028	.016	.001	...	6.5	7.0	7.0
Patchogue river	3	14	.066	.008	.001	..	6.0	11.0	11.0
Swan river	0	10	.042	.016	.002	.05	6.5	9.0	9.0
Mud creek	1	11	.032	.011	.002	.05	6.0	9.0	9.0
Carman's river	1	9	.036	.020	.002	.05	7.0	12.5	12.5

that have drained into the surface streams, and they show somewhat greater turbidity and color and slightly more organic matter than the normal ground-water, because of some surface washings and their passage through swamps.

The surface streams north of the south shore villages in Suffolk county now drain but sparsely populated watersheds, and would doubtless be reasonably safe for domestic use for some years without filtration. Eventually they would become polluted by the increasing population on their watersheds, as have many of the surface-waters in Nassau and Queens counties, which have been abandoned or in some instances have been filtered before delivery to Brooklyn.

Aside from the inexpediency of appropriating some of these surface-waters in Suffolk county, there is certainly no merit in collecting them and filtering out the organic matter and surface washings, when it is possible to intercept much of the same water in the ground before it reaches the streams.

WATERS OF THE RIDGEWOOD SUPPLY

It is interesting to compare the Suffolk County waters with those of the Ridgewood supply of Brooklyn borough, which is obtained in southern Nassau and Queens counties. The following analysis of the supply taken at the Ridgewood reservoirs represents averages of two weeks in October, 1907, coincident with the collection of many of the Suffolk County waters:

Temperature	62° F.
Turbidity	3.5
Color	15.0
Albumenoid ammonia	.030
Free ammonia	.018
Nitrites	.003
Nitrates	1.38
Total solids	......
Fixed solids	81.0
Chlorine	9.0
Hardness	31.0
Alkalinity	15.0
Iron	0.58
Bacteria per cubic centimeter (48 hours at 20° C.)	207
Total microscopic organisms	62

Comparison with Suffolk County Waters

It is evident that the normal ground-waters and even the waters of the public supplies in Suffolk county are better than the water now furnished the City by the Ridgewood system. It is important to explain, however, that the general quality of the Ridgewood supply is impaired by the water from some of the surface streams and by the high mineral contents of the waters delivered by a few stations on the "old watershed," in the westerly portion of the system, as shown by the analysis of the water from each station in Table 10. It is the purpose of this discussion to show that the high mineral contents of the waters of these stations result from their proximity to the salt water of Jamaica bay, and from the existence of a large population on a portion of the tributary watershed. It is intended to suggest, also, that the solution of the large amount of iron in some of the supplies may be occasioned by the agency of organic matter near the stations.

Doubtless only the great need of water in Brooklyn borough prevents the abandonment or reduction in pumpage of the stations now yielding an unsatisfactory supply. As soon as new sources are developed a great improvement can be effected.

The surface character of the Suffolk County watersheds and the underlying water bearing strata are much the same as in western Long Island, and a thorough understanding of the causes of the deterioration of portions of the Ridgewood supply is necessary, in order that in constructing the proposed works in Suffolk county the original purity of the supply may be maintained.

Comparison with Other Supplies

The waters of the Ridgewood system compare favorably with the other large supplies in this country and abroad, both in the amount of organic matter and in the dissolved mineral content. This is shown in Table 11, page 143. The quality of a water-supply is, after all, purely relative; a water that occasions no complaint in one city would not be tolerated in another. Still, the public is being educated all the time to higher standards in water-supply, as well as in business ethics, and works cannot be laid out to-day to provide a supply that is not in every way attractive and absolutely safe for domestic use.

TABLE 10

Analyses of Waters of the Ridgewood Supply
Parts per Million

Source of Sample	Nitrates	Total Solids	Chlorine	Hardness	Iron
SURFACE-WATERS					
Baisleys' filters	0.50	111	7.1	39	0.10
Springfield filters	1.60	137	10.4	53	0.40
Springfield pond	1.60	137	10.1	43	0.85
Smith's pond	0.35	70	6.2	17	0.60
Valley stream	1.50	80	7.4	23	0.55
Pine's pond	1.05	77	7.1	21	0.30
Shodack brook	0.65	62	5.2	17	0.20
Hempstead pond	0.20	67	6.4	16	0.55
Hempstead storage reservoir	0.30	60	5.4	18	0.15
Hempstead filters	2.10	82	10.3	23	0.20
Millburn pond	0.75	82	6.6	20	0.20
East Meadow pond	0.40	58	5.4	14	0.35
Newbridge pond	0.35	55	5.6	8	0.25
Wantagh pond	0.35	..	5.0	14	0.15
Massapequa pond	0.25	76	5.8	10	0.15
Millburn pumping-station	0.40	66	5.4	17	0.25
GROUND-WATERS					
Spring Creek deep wells	1.45	322	13.0	200	0.70
Spring Creek shallow wells	4.00	402	79.0	165	0.30
Aqueduct	9.10	187	11.3	42	0.15
Oconee	3.10	139	7.8	72	0.40
Morris park	8.40	198	23.8	76	0.05
Baisley's	3.30	165	26.0	66	0.10
Jameco deep	0.05	119	5.1	68	0.55
Jameco shallow	2.70	201	32.0	68	7.50
St. Albans	1.05	117	8.1	38	7.40
Springfield	0.05	67	4.2	14	2.40
Rosedale	0.25	107	6.0	34	5.80
Forest stream	1.20	75	6.4	29	0.55
Clear stream	1.90	90	6.9	30	0.20
Watt's pond	0.10	58	4.0	13	1.65
Watt's Pond shallow	3.00	96	6.9	25	4.40
Agawam	0.40	55	5.0	13	0.35
Merrick	0.55	54	5.3	18	0.15
Matowa	0.15	45	4.0	11	0.10
Wantagh	0.50	42	3.1	10	0.40
Massapequa	0.20	48	4.9	17	0.20
Wantagh infiltration gallery	0.65	62	5.5	22	0.10
Seaford Station infiltration gallery	1.10	49	7.0	20	0.10
Massapequa infiltration gallery	0.55	50	6.1	17	0.10
Carman's infiltration gallery	0.50	46	5.9	16	0.10

TABLE 11

Comparison of Ridgewood Supply with Waters of Large Cities in This Country and Abroad

City	Date	Turbidity	Color	Albumenoid Ammonia	Free Ammonia	Nitrite	Nitrate	Total Solids	Chlorine	Hardness	Alkalinity	Iron
New York												
Ridgewood supply	1907	3.5	15	0.030	0.018	0.003	1.38	*81.0	9.0	31.0	15.0	0.58
Croton supply	1908	Slight	Slight Yellow	0.174	0.038	....	0.20	63.0	1.8	33.8	11.7	....
Boston, Mass.												
Sudbury and Nashua River supplies	1906	..	36	0.161	0.028	0.001	0.05	33.5	2.4	7.0	....	....
Providence, R. I.												
Pawtuxet supply	1902	Slight	41	0.224	0.005	0.001	0.13	61.8	5.0	17.1	9.6	....
Philadelphia, Pa.												
Schuylkill River supply	....	..	..	0.130	0.010	0.005	0.22	125.0	6.5	36.2	6.5	....
Cleveland, Ohio												
Lake Erie supply	1904	40	22	0.108	0.016	0.007	0.05	162.0	8.8	97.0	92.0	0.70
Chicago, Ill.												
Lake Michigan	1900	Slight	..	0.192	0.012	Trace	0.38	130.0	3.1	....	....	....
St. Louis, Mo.												
Mississippi River supply	1906	..	..	0.172	0.086	0.012	1.00	120.0	6.0	....	34.0	....
London, England	1900	..	..	0.266	0.010	....	1.99	285.0	19.0	....	....	....
Berlin, Germany												
Tegelersee supply (ground-water)	....	..	..	....	....	....	....	210.0	16.2	....	....	**1.30
Dresden, Germany												
Galoppe and Tolkenwitz (ground-water works)	....	..	..	....	....	....	....	179.0	15.1	....	....	....
Amsterdam, Holland												
Dune supply (ground-water)	....	..	..	0.031	0.253	....	1.25	350.0	34.8	....	....	**5.0

*Fixed solids **Before filtration

INFLOW OF SEA-WATER

One of the most serious sources of the impairment of the Ridgewood waters is the brackish water that reaches some of the stations nearest the south shore bays, and which accounts for most of the chlorides and some of the hardness and alkalinity in the supply. The amount of the dissolved sea-salts in the Ridgewood supply has never been sufficiently great to be sensible to the taste, but the water has sometimes been too hard for domestic use and unfit for some manufacturing purposes.

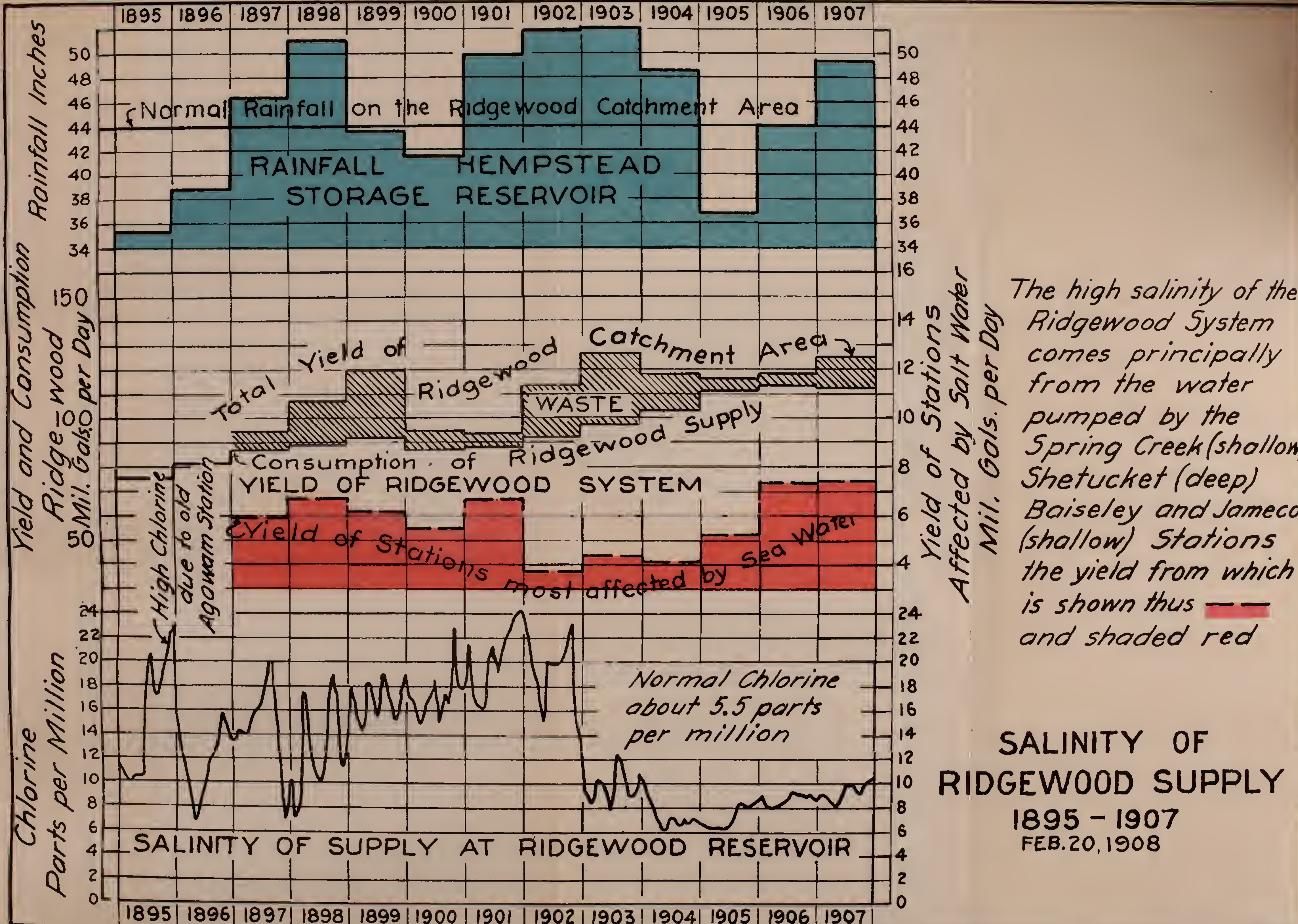
The following partial analysis from page 519 of the Burr-Hering-Freeman report, shows the principal mineral ingredients of sea-water:

	Parts per million
Sodium chloride	26,430
Magnesium chloride	3,150
Magnesium sulphate	1,783
Calcium sulphate	1,330
Silica	120
Calcium carbonate	56
Magnesium carbonate	trace
Oxide of iron	trace
Total	32,869

Evidently, about 90 per cent. by weight of the salts dissolved in sea-water are chlorides; over nine per cent. are sulphates, and less than 0.2 per cent. is carbonate. A high chlorine content and comparatively low hardness and alkalinity in any ground-water suggest, therefore, the presence of sea-water.

Chlorine in Ridgewood Supply

The amount of chlorine in the Ridgewood supply during the past eleven years is shown on Sheet 11, Acc. L 615, with the average monthly yield of the whole watershed, the delivery of those stations most affected by sea-water, and the annual rainfall at Hempstead reservoir.



SALINITY OF RIDGEWOOD SUPPLY
1895 - 1907
FEB. 20, 1908

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The original Brooklyn supply from surface streams contained from five to six parts of chlorine per million, which is the normal chlorine in southern Long Island. A large increase came with the development of the ground-waters. That shown on this diagram, in 1895, was occasioned by the pumping of the wells at the old Agawam station, which was soon after abandoned for the present site. In 1897, following several years of low rainfall, the heavy draft upon the Spring Creek, Baisley's and Jameco stations raised the chlorine to a high figure, and in 1899 the water from the deep wells at Shetucket station contributed a large amount.

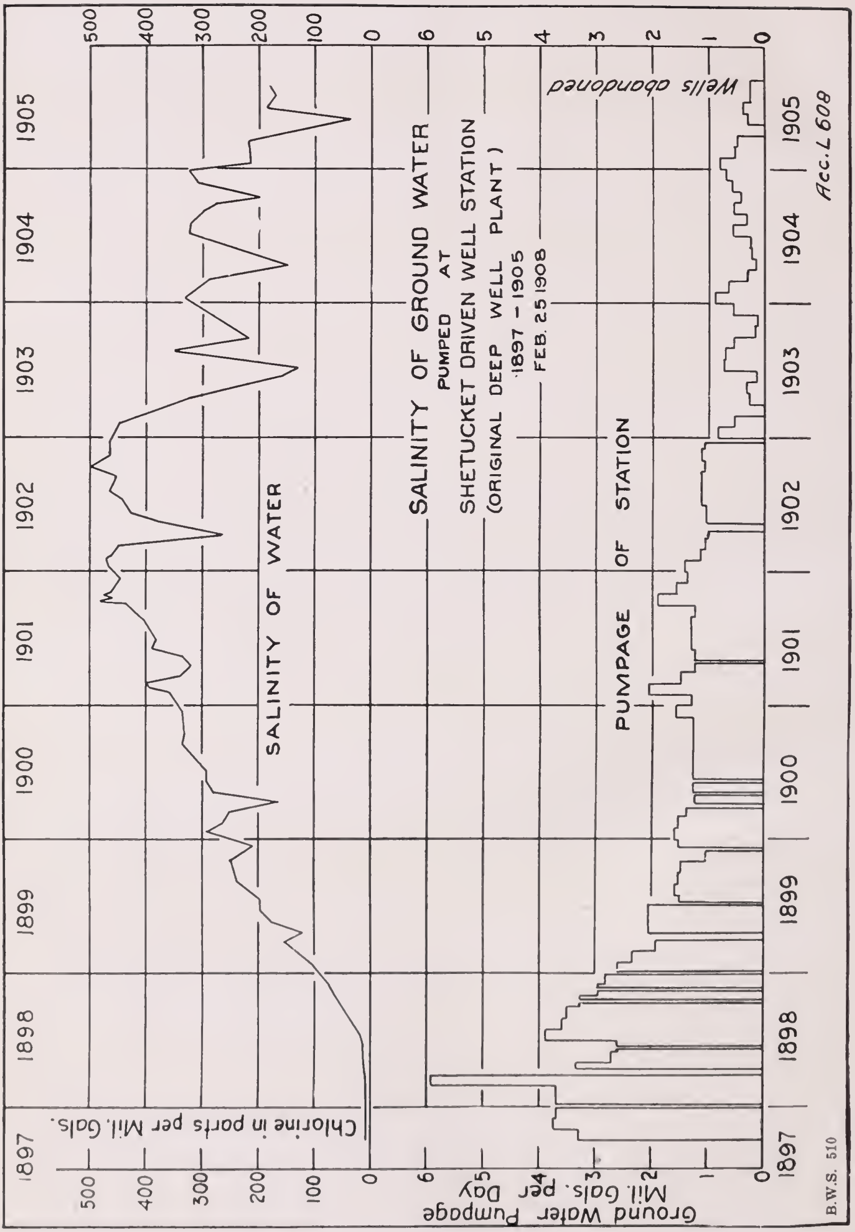
The stations delivering brackish water were shut down from time to time and parts of their well equipment cut out; but only temporary relief was secured until 1903, when the high rainfall increased the seaward movement of the fresh water, and the construction of additional ground-water collecting works permitted the sources of objectionable water to be abandoned or the pumpage greatly reduced. By this means the chlorine was reduced in 1904 to six parts per million, which is but slightly above the normal. Since that time the amount has, however, slowly increased as a result of the heavy draft upon the watershed, until, during the fall of the past year, it reached at one time 12 parts per million.

Old Shetucket Driven-Well Station

The record of the yield of the old Shetucket station furnishes one of the most interesting examples of the danger resulting from collecting ground-water near the sea. This station was situated just south of the conduit on the edge of the salt marshes about three miles from Ridgewood pumping-station and originally comprised twelve 8-inch wells, 167 to 180 feet in depth. These wells drew their supply from water bearing sands below a clay stratum 125 feet beneath the surface.

Sheet 12, Acc. L 608, which is an extension of that on page 415 of the Burr-Hering-Freeman report, shows the operation of this station from 1897 to 1905, inclusive. The plant was first operated at a rate of nearly four million gallons per day for the last few months of 1897, and yielded a satisfactory supply, having only 4.5 parts of chlorine per million. In the following March, 1898, when the rate of pumping was increased to six million gallons per day, the chlorine showed a slight increase and the amount continued to rise, although the

SHEET 12



SALINITY OF GROUND WATER
PUMPED AT
SHETUCKET DRIVEN WELL STATION
(ORIGINAL DEEP WELL PLANT)
1897 – 1905
FEB. 25 1908
SALINITY OF WATER
PUMPAGE OF STATION
Wells abandoned
Chlorine in parts per Mil. Gals.
Ground Water Pumpage
Mil. Gals. per Day
1897
1898
1899
1900
1901
1902
1903
1904
1905
500
400
300
200
100
0
6
5
4
3
2
1
0
Acc. L 608
B.W.S. 510

yield of the station was reduced to four million gallons per day, and later, as the salinity continued to increase, to one million gallons per day. The chlorine in 1902 rose to 500 parts per million.

In 1903 the pumping was further reduced to an average of 0.5 million gallons per day, and continued at this rate until August, 1905. The chlorine did not decrease materially with this low rate of pumping and the deep wells were then abandoned. Investigation in 1903 showed that the brackish water came from the bay through the strata beneath the clay bed. The sands above this clay contained only 6 to 20 parts of chlorine, and in 1907 shallow wells were driven at the Shetucket station to replace the deep ones.

One important fact is brought out by the operation of the Shetucket station, which is confirmed elsewhere, that the original freshness of the ground-water in the sands is not restored at once by shutting down the plant and permitting the ground-water to rise to its original level. When the sea-water once reaches a system of wells the only remedy is to abandon them. Probably only in the course of many years will the salt water be entirely washed from the sands by the slowly moving fresh waters escaping into the sea.

Other Stations of the Ridgewood System

The shallow wells of the Spring Creek, Baiseley's and Jameco driven-well stations have also yielded brackish water. The studies upon the operation of these stations by the Department of Water Supply are given in the report of the Burr-Hering-Freeman Commission, pages 410 to 420. At each of these plants the brackish water seemed to reach the wells from Jamaica bay in a coarse stratum that perhaps represented an old surface channel. The yield of Spring Creek station has been reduced during the past three years, and the yield of Baiseley's station has been cut down to but little over 0.5 million gallons per day.

The new Morris Park and Aqueduct stations are providing water quite high in chlorine, and it is probable, in a year of low rainfall, that their delivery would have to be considerably curtailed.

The only station on the "new watershed" east of Freeport which has yielded brackish water was the old Agawam station. This was located a short distance north of the head of

the salt-water creek at the Merrick road, and when placed in operation yielded a supply so high in chlorines as to increase the salinity of the whole Ridgewood supply during the latter part of 1895. The station was moved 700 feet north to the present location, where no difficulty has been experienced. It should be noted that the water-table at the present site is, to some extent, sustained by the overflow and seepage from the East Meadow pond, a few hundred feet above. (See the Burr-Hering-Freeman report, Plate XIII, page 836).

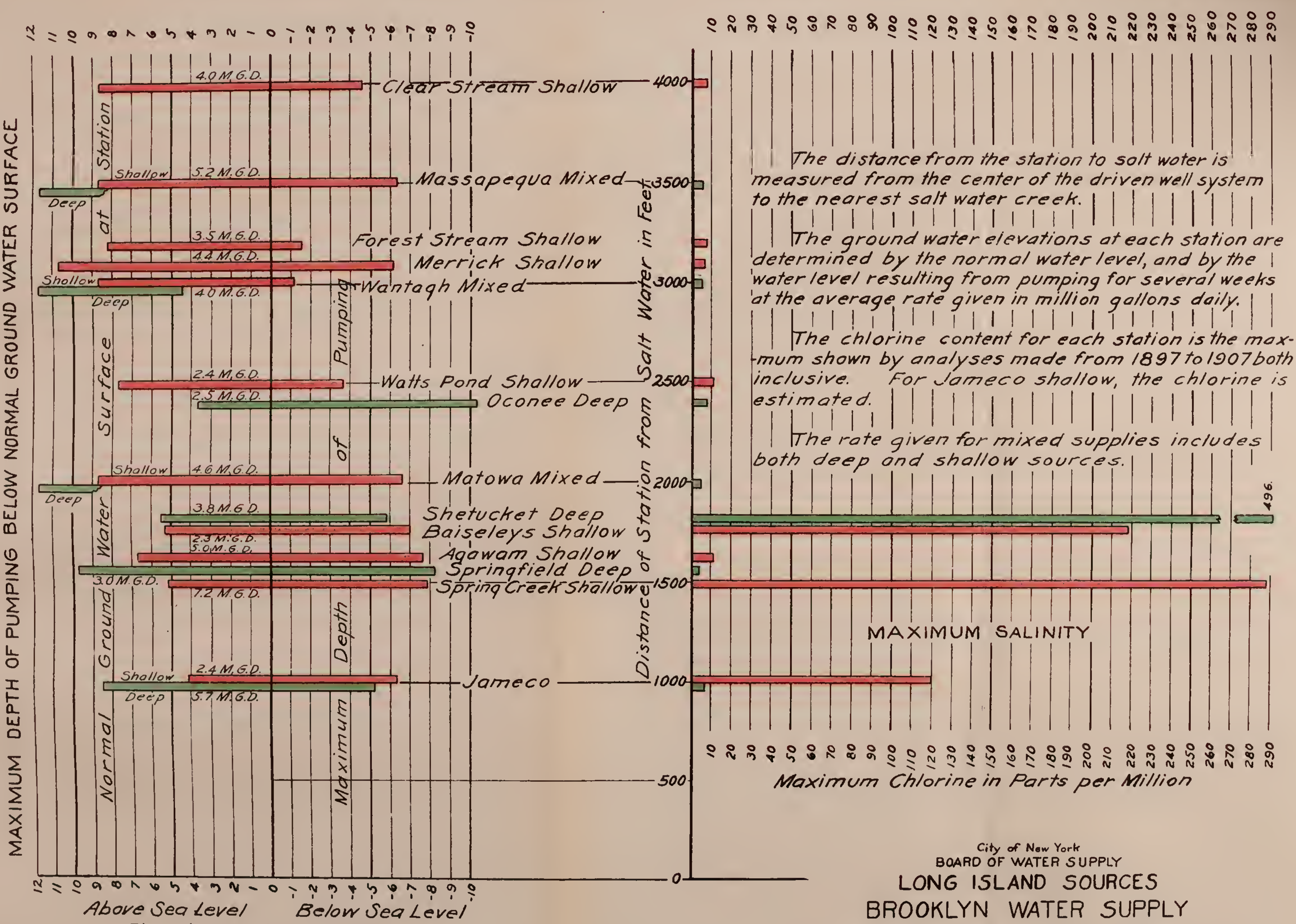
The amount of chlorine in the supplies from the Shetucket, Jameco, Spring Creek and Baiseley's driven-well stations, with the corresponding ground-water elevations at these plants, are shown on Sheet 21, Acc. LJ 195.

Location of Ground-Water Works of Ridgewood System

The stations of the Ridgewood system that have not been affected by the sea-water evidently owe their immunity to the distance from the sea, the hight of the water-table and the lack of free movement of the ground-waters where they are situated. The amount of chlorine at the driven-well stations of the Ridgewood system are shown on Sheet 13, Acc. L J 188, with the distance of each station from the salt water in the south shore bays or estuaries tributary to them, the general hight of the normal ground-water surface, the pumpage, the maximum salinity and the corresponding depth of pumping.

This diagram shows that brackish water has not reached the wells of any station that is situated over 2,000 feet from the salt water. Several other stations within this distance, and some but little farther away, notably the Oconee station, would doubtless have pumped brackish water but for the fineness of the water bearing strata, the low pumpage and the small area of influence about the wells. More ground-water has been developed on the "old watershed" and the driven-well stations have been pumped more continuously than on the new.

Several stations of the Brooklyn works in Nassau county, particularly the Agawam, Matowa and other driven-well stations in the "new watershed," are but little farther from the salt water than these stations where salt water has been obtained, and not one of them is located where the normal ground-water surface was originally higher than 10 or 12 feet above mean sea. It appears very probable, therefore, that salt or brackish water would have been obtained at many of



Note that sea water has not reached any station over 2000 feet from salt water in bays or creeks. Observe however that above stations are not a continuous development.

City of New York
BOARD OF WATER SUPPLY

LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
WATER LEVELS AND CHLORINE
DRIVEN WELL STATIONS, RIDGEWOOD SYSTEM

From Records of the Department of Water Supply
FEBRUARY 25, 1908.

M. B. BROWN PRINTING & BINDING CO., N. Y.

these stations had it been the practice in past years to operate them continuously, instead of a few months a year in dry weather, or had these stations been equipped to pump the ground-water sufficiently low to draw a large amount of storage.

It should further be noted, in considering the stations of the Ridgewood system, that they are a mile or two apart and undoubtedly some water escapes to the sea between them. Furthermore, the ground-water surface at several stations in the new watershed is maintained by the surface-water in adjacent ponds. Even though the wells at many of these stations were pumped continuously for several years and the ground-water surface in their immediate vicinity maintained below sea-level, their operation would not necessarily prove that it would be safe, on the same location, to pump to equal depths a continuous line of wells that permitted very little water to escape towards the bay, to keep up the level of the water-table south of the wells.

Before considering the location of the Ridgewood works as a precedent for the proposed system in Suffolk county, it should be remembered that both the original conduit out to Smith's pond, near Rockville Center, and the new conduit from Millburn to Massapequa were built to intercept the flows of the surface streams, and, therefore, were placed as near the south shore as the surface of the ground and the aqueduct grades permitted. The ground-water pumping-stations that were constructed later were not considered in the original works, and, when built, were naturally placed near the existing aqueducts.

EQUILIBRIUM BETWEEN FRESH AND SALT WATER

There is much evidence in the infiltration of brackish water to the wells of the Ridgewood works, and the salt water actually found in deep wells on the outlying islands and beaches, that the salt water exists at considerable depths in the deep sands and gravels near the shores of Long Island. A brief consideration of the equilibrium between the fresh water and the heavier brackish water shows that the salt water must fill the deep strata beneath the shores, unless the fresh water is under sufficient head to overcome the greater specific gravity of the salt water and keep it out.

The freedom of communication between the fresh ground-waters near the south shore of Long Island and the bodies of salt water in the bays and ocean beyond is well exhibited by the observations of Mr. A. C. Veatch of the U. S. Geological Survey in 1903. (See "Underground Water Resources of Long Island, New York," 1906, Professional Paper 44, pages 70 and 71).

Studies in Holland and Belgium

The equilibrium between the fresh ground-water and the sea-water has received much study in Holland and Belgium, where ground-water supplies are obtained, near the sea, from sand and gravel formations. On Sheet 14, Acc. L 339, is shown an ideal section of the sand dunes in northern Holland, which has been made up from the studies in that vicinity. The first figure exhibits the normal undisturbed relations of the fresh and salt water before the lowering of the surface of the fresh water by artificial means. Referring to this diagram, F is the fresh-water head above sea-level at some point on the section, as A; and S is the depth from sea-level to the salt water immediately below this point. If d is the specific gravity of the salt water in the saturated sands, it is clear that for equilibrium the total depth of fresh water, F + S, must be d x S; from which the depth of salt water below sea-level at the point A will be $S = \frac{F}{d-1}$. If the specific gravity of the water in the sands is equivalent to that in the North sea, 1.025, the depth of salt water below sea-level will be 40 times the fresh-water head above sea-level. Similarly, if the salt water had a specific gravity of only 1.015, the salt water would be found at a depth of 67 times the fresh-water head.

In Figure 2 of this same diagram, the effect is shown of lowering the water-table through a canal excavated in the center of the section. As the ground-water surface is lowered and the stored water abstracted, the salt water naturally rises to take its place. Evidently, if the fresh water is lowered to sea-level, brackish water will be obtained in this canal.

The line of contact between the fresh and salt waters would be naturally modified by inequalities in the character of the saturated strata, and the freedom of communication in a vertical direction near the line of contact, as shown in the

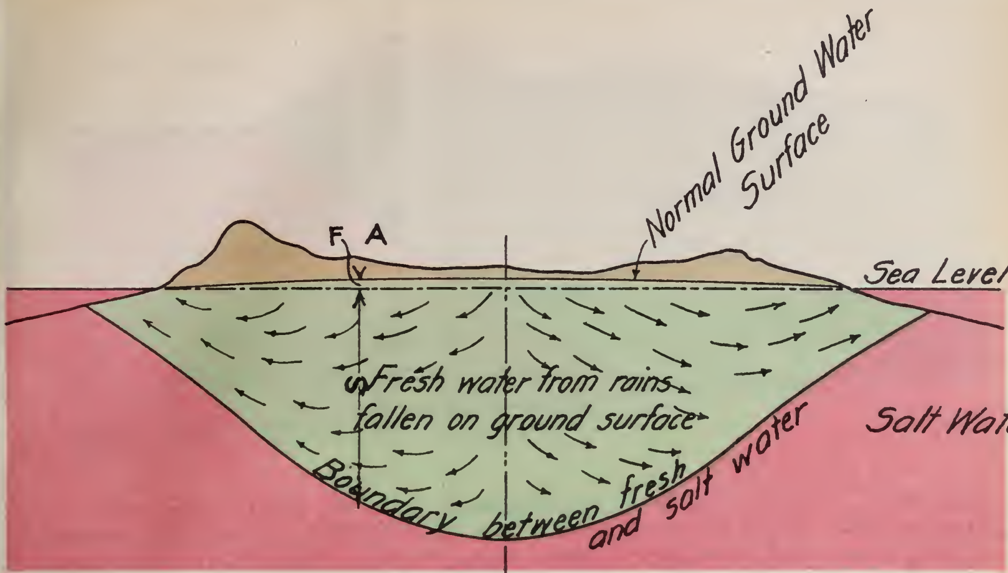


FIGURE NO. 1
NORMAL RELATION BETWEEN FRESH AND SALT WATER

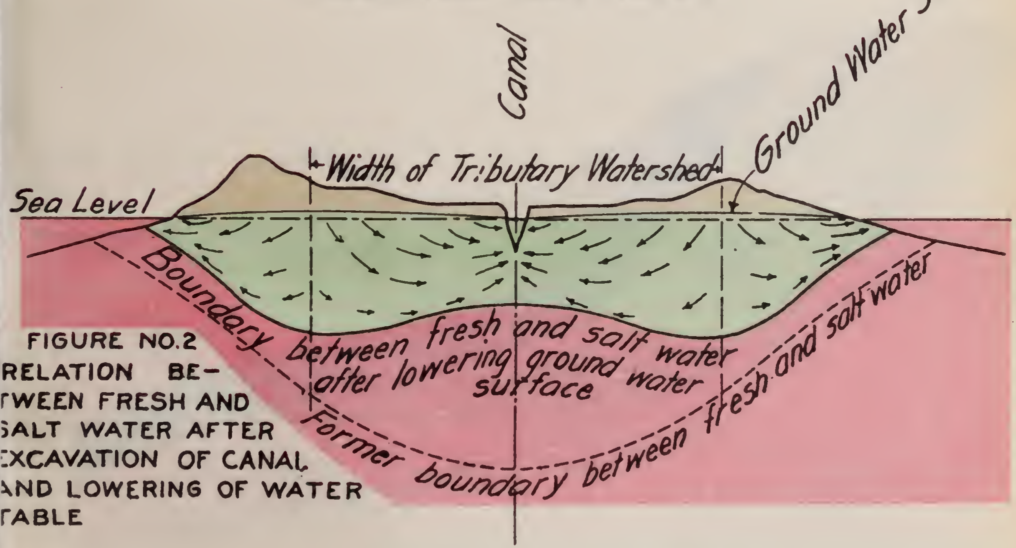


FIGURE NO. 2
RELATION BETWEEN FRESH AND SALT WATER AFTER EXCAVATION OF CANAL AND LOWERING OF WATER TABLE

From proceedings of Royal (Dutch) Institute of Engineers.

IDEAL SECTION OF NORTH HOLLAND DUNES SHOWING EQUILIBRIUM BETWEEN FRESH AND SALT WATER IN HOMOGENEOUS POROUS STRATA

Jan. 28, 1908

Acc. L 339.

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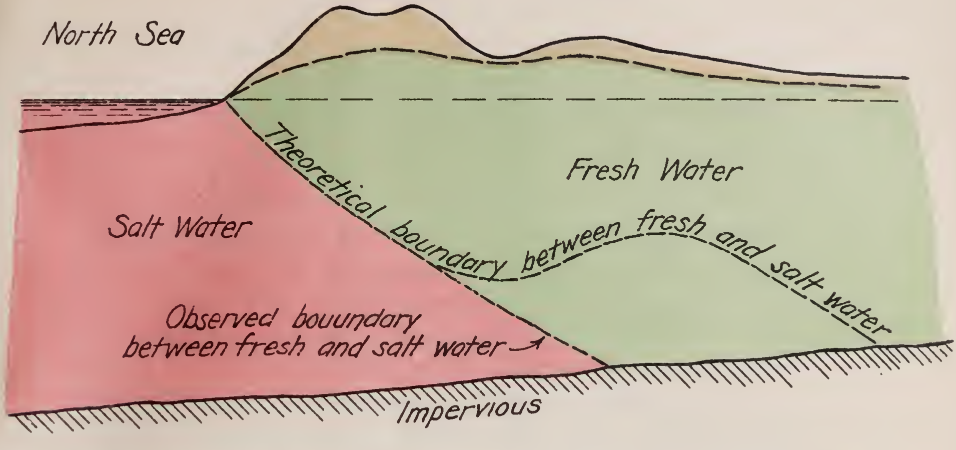
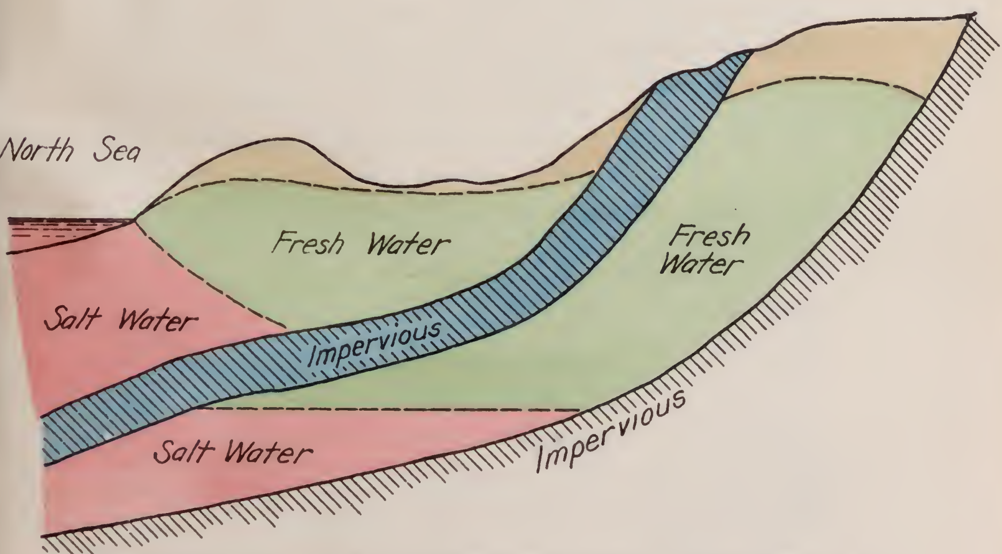


SECTION OF COAST WHERE SUBSTRATA ARE UNIFORMLY PERVIOUS SHOWING OBSERVED DIFFERENCE BETWEEN THEORETICAL AND ACTUAL BOUNDARY BETWEEN SALT AND FRESH WATER DUE SEAWARD MOVEMENT OF FRESH WATER



SECTION OF COAST WHERE POSITION OF SALT WATER IS MODIFIED BY IMPERVIOUS STRATA

RELATION OF
SALT AND FRESH GROUND WATER
ON THE
COAST OF BELGIUM

From "Journal für Gasbeleuchtung und Wasserversorgung" May 9, 1903
Jan. 24, 1908

M. B. BROWN PRINTING & BINDING CO., N. Y

second figure on Sheet 15, Acc. L 592, where impervious clay beds exist.

Investigations of the Amsterdam Dune Supply

The most thorough investigation of the hydrology of fresh and salt waters has been made by the Amsterdam Water Works, which were briefly described in the Transactions of the American Society of Civil Engineers, Volume LIV, Part D, page 169, and more fully in the Transactions of the Royal (Dutch) Institute of Engineers, February 1, 1904.

A cross-section of the dune works near Haarlem and Zandvoort, from the North sea to the Haarlemermeer, Sheet 16, Acc. L 580, which has been taken from the latter paper, shows the canals from which the ground-waters are collected, the geology of the substrata and the movement and salinity of the ground-waters. The normal relations between the fresh and salt waters, which must have been originally as shown in the ideal section of the dunes, Sheet 14, Acc. L 339, have been modified by the pumping out of the polders behind the dunes. In spite of the rains that have fallen on the surface of this polder for hundreds of years, the waters in the polder are brackish because, being lower than the North sea, the salt water flows inland to them beneath the dunes.

The ground-water supply for Amsterdam is, for the most part, gathered by the canals from the sands above the first clay stratum. Deep wells have, however, been driven into the second water horizon below this upper clay stratum by which to collect the fresh waters that have slowly percolated from the surface. These wells are only intended to furnish a temporary supply to meet the city's demands until such times as new sources east of the city may be developed. The engineers of the works know that the supply is small that comes from the surface to these lower sands through the semi-impervious stratum, and they realize that as soon as the stored water is drawn at a greater rate than that of the downward movement from above and the fresh-water pressure there is reduced, the salt water will enter and the wells must be abandoned.

There is much of interest in this diagram in the relative pressures in the several water horizons, and in the direction of ground-water movement and the methods employed during the Amsterdam investigations that could be profitably applied to Long Island problems. If the ground-water in southern Suffolk county were lowered to a depth of 15 feet below sea-

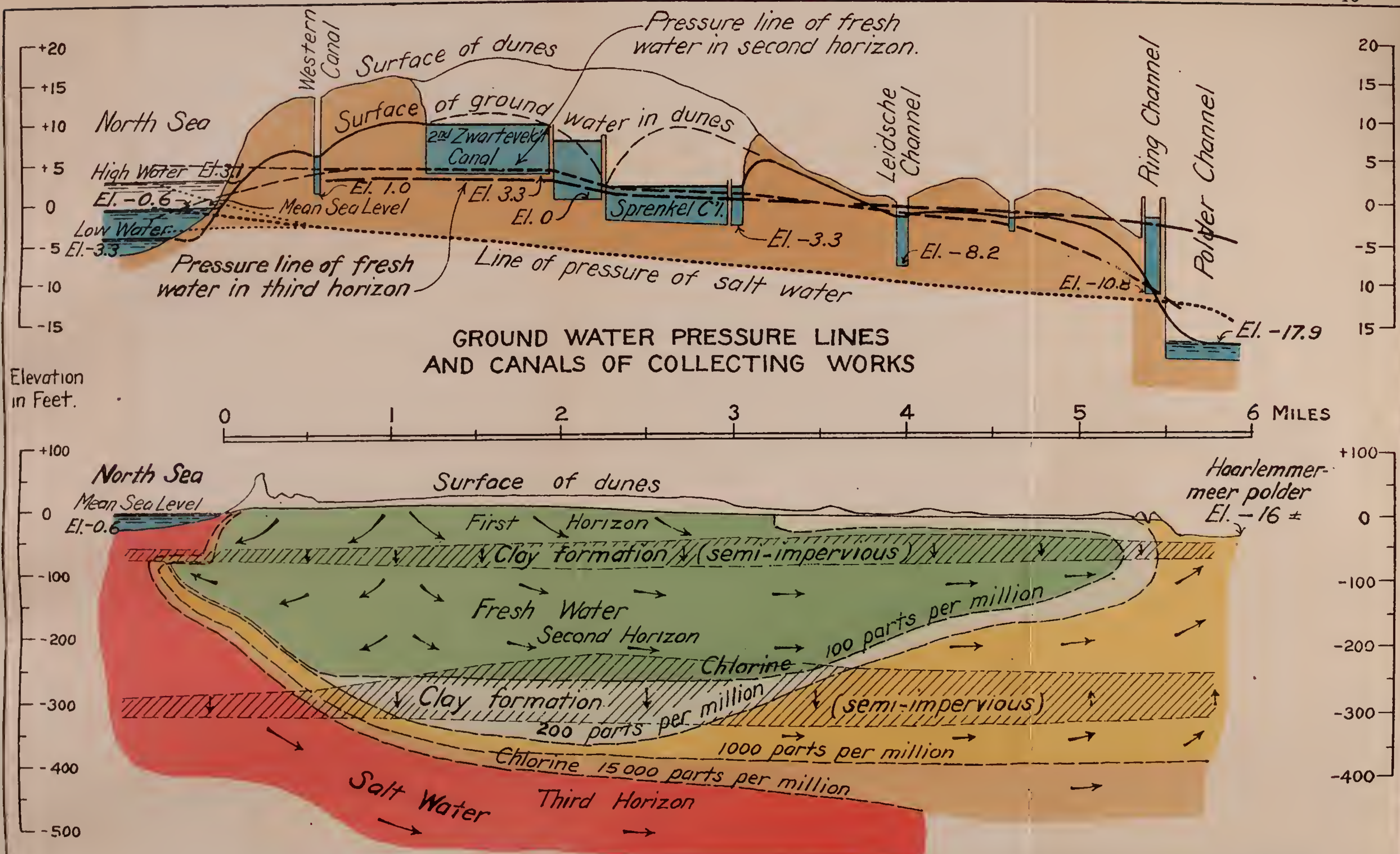
level by means of deep wells driven at a distance of five miles from the shore, and a continuous stratum of clay separated the upper and lower water horizons, the conditions would be identical with those shown in this diagram at the westerly edge of the Haarlemermeer polder, and salt water would just as surely, in the course of time, enter the wells as it does the polder canals.

Long Island Relations

On Sheet 17, Acc. L 105, two ideal sections of Long Island similar to those of the Holland dune have been constructed from the available data on the hydrostatic conditions of the deep ground-waters, assuming in this diagram that there exists homogeneous and pervious material down to bed-rock.

The first section represents roughly the present normal relation in Suffolk county between the fresh and the salt water in the unconsolidated strata. It has been found that the hydrostatic head on the deep waters in the center of the island is 10 to 20 feet below the surface of the main water-table, and there are artesian heads on both the north and the south shores from 5 to 15 feet above sea-level. From these data, the deep pressure gradients have been drawn and the lines of contact between the fresh and salt waters estimated.

The arrows indicate the downward movement of the ground-waters in the center of the island from which results the observed loss of head between the surface and the deep waters; also the lateral movement of the waters from the middle of the island, in both directions, to the sea, and the upward movement and the emergence of this deep water beyond the shores. This general movement has been well confirmed by the character of the water found in deep wells near the shore. These deep waters have generally much less chlorine than the surface-waters in the same locality, but quite the same as the surface-waters in the center of the island. In drawing the arrows, showing the general direction of the ground-water movement, their lengths have been made proportional to the probable velocities of the ground-water just to illustrate how exceedingly slow is the motion of these waters, and, consequently, how perfect is their purification. The magnitude of the movement of the ground-water in the lowest strata is doubtless greatly exaggerated, as most of the seaward flow is believed to take place in the yellow gravels in the first 100 to 500 feet of the water bearing sands.



GROUND WATER PRESSURE LINES AND CANALS OF COLLECTING WORKS

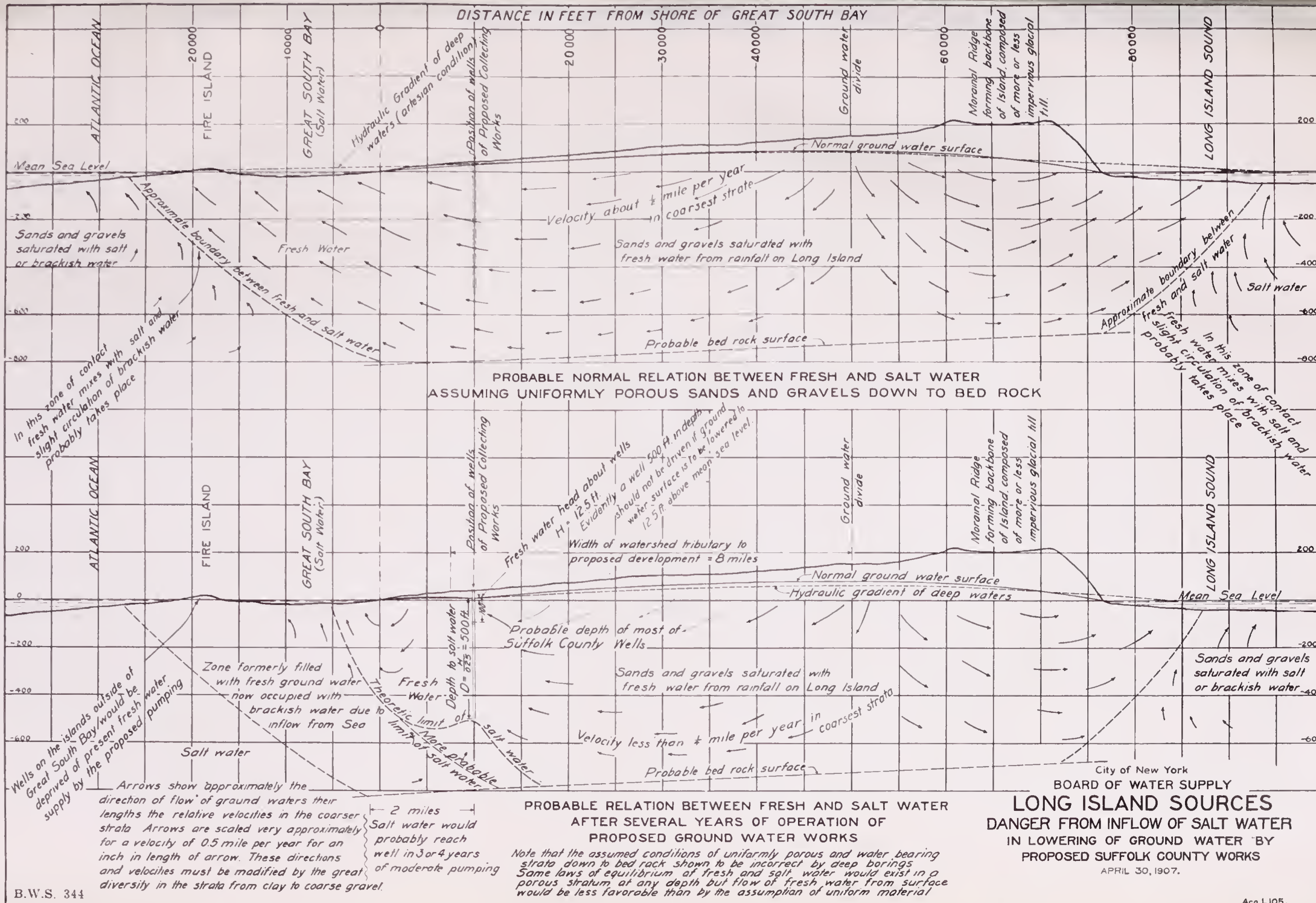
GEOLOGICAL CROSS SECTION OF THE DUNES SHOWING DIRECTION OF MOVEMENT AND SALINITY OF GROUND WATERS

AMSTERDAM WATER WORKS

INVESTIGATION OF DUNE SOURCES NEAR HAARLEM AND ZANDVOORT

From Transactions of Royal (Dutch) Institute of Engineers, Feb. 1, 1904.

M. B. BROWN PRINTING & BINDING CO., N. Y.


DISTANCE IN FEET FROM SHORE OF GREAT SOUTH BAY
20000
10000
0
20000
30000
40000
60000
80000
ATLANTIC OCEAN
FIRE ISLAND
GREAT SOUTH BAY (Salt Water)
Hydraulic Gradient of deep waters (artesian condition)
Position of wells of Proposed Collecting Works
Ground water divide
Morainal Ridge forming backbone of Island, composed of more or less impervious glacial till.
LONG ISLAND SOUND
Mean Sea Level
Normal ground water surface
Velocity about ¼ mile per year in coarsest strata
Sands and gravels saturated with salt or brackish water
Approximate boundary between fresh and salt water
Fresh Water
Sands and gravels saturated with fresh water from rainfall on Long Island
Salt water
In this zone of contact fresh water mixes with salt and slight circulation of brackish water probably takes place
Probable bed rock surface
PROBABLE NORMAL RELATION BETWEEN FRESH AND SALT WATER
ASSUMING UNIFORMLY POROUS SANDS AND GRAVELS DOWN TO BED ROCK
Fresh water head about wells H = 12.5 ft.
Evidently a well 500 ft. in depth should not be driven if ground water surface is to be lowered to 12.5 ft. above mean sea level.
Width of watershed tributary to proposed development = 8 miles
Hydraulic gradient of deep waters
Probable depth of most of Suffolk County Wells
Depth to salt water $D = \frac{H}{.025} = 500$ ft.
Zone formerly filled with fresh ground water now occupied with brackish water due to inflow from Sea
Fresh Water
Theoretic limit of salt water
More probable limit of salt water
Velocity less than ¼ mile per year in coarsest strata
Wells on the islands outside of Great South Bay would be deprived of present fresh water supply by the proposed pumping
Arrows show approximately the direction of flow of ground waters their lengths the relative velocities in the coarser strata. Arrows are scaled very approximately for a velocity of 0.5 mile per year for an inch in length of arrow. These directions and velocities must be modified by the great diversity in the strata from clay to coarse gravel.
2 miles
Salt water would probably reach well in 3 or 4 years of moderate pumping
PROBABLE RELATION BETWEEN FRESH AND SALT WATER
AFTER SEVERAL YEARS OF OPERATION OF
PROPOSED GROUND WATER WORKS
Note that the assumed conditions of uniformly porous and water bearing strata down to bed rock shown to be incorrect by deep borings. Same laws of equilibrium of fresh and salt water would exist in a porous stratum at any depth but flow of fresh water from surface would be less favorable than by the assumption of uniform material
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
DANGER FROM INFLOW OF SALT WATER
IN LOWERING OF GROUND WATER BY
PROPOSED SUFFOLK COUNTY WORKS
APRIL 30, 1907.
B.W.S. 344
Aco L105.

The second or lower section of this diagram shows roughly the effect on the normal line of contact between the fresh and salt water of pumping down the ground-water on the south shore. The salt water would naturally flow inland and rise as the ground-water surface was lowered until, if this lowering was continued for some years, brackish water would be obtained in the wells. This section brings out the interesting fact that when the water-table is lowered under these conditions, storage is drawn not only from the surface of the ground-water reservoirs, but some fresh water is evidently abstracted from the bottom, as salt water advances toward the collecting works and partially fills the space previously occupied by the fresh water. The amount of this storage, in any year, from some considerations of the Ridgewood works, does not appear to be large because of the slow advance of the sea-water and the mixture of salt and fresh waters that occurs.

It would not be difficult to detect the advance of salt water to the proposed collecting works if test-wells were driven along the shore and samples taken at intervals for chlorine examination. Such wells should be driven before the Suffolk County works are placed in operation.

If we assume, as in this sketch, a well 500 feet in depth, it is evident that the salt water would enter the bottom when the fresh-water head is drawn to the level of 12.5 feet above sea-level, providing the brackish water has the assumed specific gravity of 1.025. If the brackish water in the porous sands were diluted by a large proportion of fresh water and its specific gravity were only 1.015, brackish water would not enter this well until the fresh-water pressure head at the bottom were less than 7.5 feet above sea-level. The higher value would only be obtained after many years of operation of collecting works that intercepted the entire fresh-water movement towards the sea.

From Sheet 17, Acc. L 105, it appears that where there are no impervious clay beds between the upper and lower water bearing strata, the greatest safety against the entrance of sea-water would be secured by constructing the works in the center of the island and by maintaining on either side, between these works and the sea, a fresh-water summit of at least 20 feet or more above sea-level. Such a development would, however, be very expensive, both in first cost and in operation, and it would be impossible to lower the water-table

at such wells sufficiently to draw upon as large a tributary watershed as may be obtained by the proposed works on the south shore.

As far as the deep water bearing strata have been investigated, it is very improbable that any wells would be driven as deep as 500 feet. The maximum depth of the wells is not likely to exceed those of the Ridgewood works, about 200 feet, and, from present indications, they may not, perhaps, be greater than 150 feet in depth. These considerations of the equilibrium of the fresh and salt waters show the advantage of the shallow wells in protecting the supply from the sea-water.

Minimum Fresh-Water Head

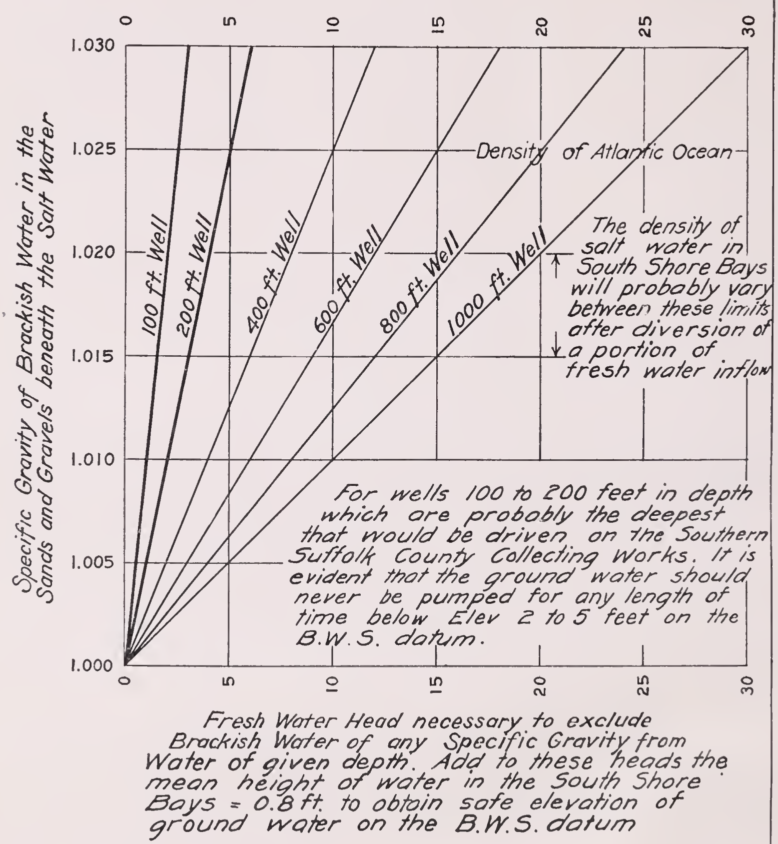
On Sheet 18, Acc. L 599, is shown graphically the minimum hight of the fresh ground-water that will exclude from wells of various depths in the saturated sands, sea-water varying from 1.005 to 1.025 in specific gravity.

The density of the sea-water off this coast is about 1.025, but the waters of the south shore bays vary in specific gravity from 1.015 to 1.020. Moriches bay has, however, a density of about 1.005. After the operation of the proposed collecting works, the density of the south shore bays will increase slightly, but it is unlikely, from the known density of the waters in Jamaica bay south of the Ridgewood collecting works, that any of these bays in Suffolk county will ever have a greater specific gravity than 1.020, and many portions will never exceed 1.015.

Referring to this diagram, it is evident that in wells from 100 to 200 feet in depth, the ground-water should never be reduced during long periods of operation below four feet above sea-level. As the south shore bays are about 0.8 foot above the B. W. S. datum plane of 1907, which is used in this report, the safe minimum ground-water elevation, on our scale of hights, would be at Elevation 5.

A ground-water supply cannot be collected without depressing its surface, and if, furthermore, the proposed works in southern Suffolk county were designed to secure enough storage to maintain the estimated yield, the amount of lowering of the ground-water surface corresponding to the storage required must be added to the minimum elevation of the ground-water shown by this diagram, in order to find the normal hight of ground-water above sea-level where it would be safe to locate wells of any given depth.

SHEET 18



SAFE HEIGHT OF GROUND WATER
AT COLLECTING WORKS
TO PREVENT ENTRANCE OF SALT WATER
Jan. 28, 1908.

B.W.S. 524

Acc. L 599

In Appendix 1 it was pointed out that a storage corresponding to about 50 million gallons per square mile should be obtained and that of this it was suggested that about half should be obtained on the main line of the collecting works. To make available this volume of storage, it would be necessary to pump down the water-table at the wells on the main line about 15 feet. If the ground-water surface were not to be drawn for any great period lower than Elevation 5, the original level on the line of the works should be 20. It is evident then, for wells from 100 to 200 feet deep, that *a location for the proposed Suffolk County development should be selected where the ground-water is at least as high as Elevation 20 feet on the B. W. S. datum.*

Location of Amsterdam Works

The only large ground-water supply near the sea with which the location of the Long Island works may be compared, is that of the dune works of Amsterdam, near Haarlem and Zandvoort, a section of which is shown on Sheet 16, Acc. L 580.

The so-called West canal of these works is the nearest to the North sea, and is only ½ mile from the shore. The surface of the water in this channel in which the ground-water is collected is, however, five to six feet above mean sea-level, and the bottom of the canal is over a foot above this level, or evidently higher than portions of the Wantagh infiltration gallery of the Brooklyn works.

Some of the other canals two to three miles from the sea are lower than the West canal. The bottom of the lowest of these, the Sprenkel canal, is three feet below mean sea-level; its water surface, however, is two feet above, so that the works are safe from the entrance of sea-water. The normal ground-water level near the dune canals was 10 to 15 feet above sea-level.

POLLUTION FROM LOCAL POPULATION

The sea-water from the south shore bays is not the only source of dissolved mineral matter in the Long Island ground-waters. In the analyses of the Suffolk County waters, attention has already been called to the large amount of chlorine and nitrates, and to the great hardness and alkalinity of the

ground-waters from wells adjacent to points of disposal of house drainage and domestic wastes.

The mineral contents of some ground-waters from the more thickly populated portions of western Long Island, given for 1902 in the Burr-Hering-Freeman report, are shown below:

Station	Parts per Million			Population per Square Mile of Watershed Estimated on Page 565 of Report of Burr-Hering-Freeman Commission
	Nitrates	Chlorine	Hardness	
Pfalzgraf Water Supply Co..	9.60	14.3	192.0	......
Blythebourne Water Co.....	5.25	7.4	126.3	3,000
Woodhaven Water Co.......	2.49	9.1	131.4	3,600
Montauk Water Co.........	5.60	19.9	119.0	2,200
Jamaica Water Co..........	7.40	15.7	88.0	......
Flatbush Water Co.........	6.72	14.1	172.0	7,000
New Lots station...........	14.18	22.1	191.9	10,000
Spring Creek deep wells.....	0.10	6.9	131.3	2,600

It should be noted that these are much harder than some of the waters of the Ridgewood system, containing the same percentage of chlorine. This excess in hardness, which is due to the local drainage, distinguishes these waters from those of the Ridgewood system which are more affected by sea-water, and, therefore, contain a larger proportion of the chlorides of salt water and less sulphates and carbonates. While the bacterial examinations show these waters to be perfectly safe, they are not altogether satisfactory for many uses because of their hardness. As the population still further increases on the watersheds of these stations, some of them will doubtless be abandoned.

Unlike Nassau and Queens counties, most of the population in southern Suffolk county is located in the villages close to the south shore, and the subsurface drainage containing a large amount of dissolved mineral matter could readily be avoided by locating the proposed line of collecting works north of these south shore villages, where the wastes from the more thickly populated areas would not drain toward the works. The ground-waters collected on the line that is here proposed should not show a much higher mineral content for many years than that of the normal ground-waters shown in Table 8, page 135, which were recently collected there.

The present population within the watershed in Suffolk county north of the south shore villages is estimated as 17,000,

which is an average of 51 per square mile. This is hardly a third, or a quarter, of the present population per square mile of the Ridgewood watershed, and explains the better quality of the Suffolk County ground-waters.

IRON AND MANGANESE IN LONG ISLAND WATERS

The yellow water bearing sands and gravels of Long Island owe their distinctive color to the film of iron oxide with which they are coated. This oxide is readily soluble upon deoxidation in contact with organic matter, and all ground-waters gathered from the yellow gravels contain more or less of the oxide in solution. The solubility of the iron oxide is well illustrated in the scrub oak country of Suffolk county, where patches of clean, white quartz sand are seen here and there, adjacent to areas of dark loam. The sand below the soil covering is quite yellow, but the iron stain on the surface particles, in contact with the vegetable humus, has been dissolved and washed away.

It is not alone, however, the surface humus that serves as the deoxidizing agent by which the iron is dissolved. It is recognized that a large amount of iron is dissolved from deep, iron-bearing gravels, near beds of peat or lignite.

Amount of Iron in Long Island Waters

On the whole, the ground-waters in southern Suffolk county are low in iron. Among the widely distributed samples taken in a survey of Suffolk County waters, the iron ranged from 0.05 to 0.9 part per million, being, except in one or two localities, less than 0.2 part. The waters in the Peconic valley are, however, noticeably high in iron, and the samples from several domestic wells are probably abnormally large because of their proximity to cesspools, or privies, the drainage from which provided the organic matter for the deoxidation and solution of the iron.

The available data on the distribution of iron in the Long Island ground-waters have been placed on Sheet 19, Acc. L 568. It is evident that the ground-waters along the south shore of the island, from Massapequa to Spring creek, contain larger amounts of iron than in southern Suffolk county, and that, in general, the iron contents increase toward the westerly limits of the Ridgewood system. On the other hand, the

ground-waters back from the shores in the central and extreme western parts of Long Island contain but little iron.

It seems significant that the ground-waters highest in iron are, in general, found in the western portion of the Ridgewood system and in the Peconic valley, where large areas of the surface are low and swampy, and are naturally covered with a considerable depth of organic matter, as indicated by the red shaded areas on this map. It should be noted that the ground-waters of the Woodhaven, Montauk and Jamaica stations, which are immediately north of the zone of highest iron contents in western Long Island, have less than 0.2 part of iron per million.

It is quite likely that the high iron contents of the waters from the deep wells of the Ridgewood stations in Queens county are the result of the deoxidizing effect of the deep beds of peat through which the ground-waters pass on their way to the wells.

This map suggests that the stations of the Ridgewood system, from Springfield to Jameco, would not, perhaps, yield waters so high in iron if they had been located a little farther north in the direction of the Woodhaven and Jamaica pumping-stations and away from the swampy valleys of the south shore.

The greatest amount of iron that is permissible in a supply is considered to be 0.4 to 0.5 part per million. A larger amount is sensible to the taste and gives trouble in the laundry and in some industrial processes. The iron in the Ridgewood supply did not exceed these figures until, during the last few years, a larger supply has been drawn in the westerly portion of the old watershed where the iron is high, as stated above.

The analyses of the Suffolk County ground-waters do not indicate that a supply from these sources would contain more iron than the waters of the Ridgewood system. The swamp areas in southern Suffolk county are smaller and the surface soils throughout the southerly portion of the county are generally freer from organic matter than those in the Ridgewood watershed. Wells driven into the yellow gravels above the lignite beds of the cretaceous deposits and on the line proposed for the collecting works in southern Suffolk county would not, probably, provide enough iron to occasion any trouble in the distribution system, or any annoyance as a

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domestic supply, or for ordinary manufacturing uses, since the supply of water in these yellow gravels is not probably drawn to any appreciable extent from the cretaceous formation below.

The iron in the swampy valley of the Peconic river is higher than elsewhere in Suffolk county, and it does not appear that the collecting works can be located to avoid it. A discussion of the treatment necessary for the removal of iron in these ground-waters is given in a subsequent appendix.

Occurrence of Manganese

Representative samples of the Suffolk County ground-waters have been taken to determine the amount and distribution of manganese, the salts of which are much more to be feared than those of iron, since they cannot be readily removed from the water.

The results are shown in the following table, with the corresponding amount of iron, and are plotted on Sheet 19, Acc. L 568.

Samples	Parts per Million	
	Iron	Manganese
Babylon water-works	0.30	0.07
Experimental station, West Islip	0.15	0.27
Bayshore water-works	0.15	0.37
Great River (well) at railroad stations	0.90	0.08
Patchogue water-works	0.30	0.20
Brookhaven (domestic well)	0.90	0.04
Calverton (domestic well)	3.50	0.30

There appears to be no relation between the occurrence of iron and manganese, although it is very likely that the conditions favorable for the solution of iron may also dissolve out the manganese.

The Bayshore Supply

It will be noted that while the iron is higher in the Babylon supply, the water of the Bayshore water-works shows more manganese. The latter supply has a noticeable "iron" taste, and it is but natural to suppose this is due to the small percentage of manganese that the water contains.

Much trouble occurred at the original Bayshore pumping-station just north of the South Country road, where the stand-

pipe still stands. The supply was drawn from shallow wells about the foot of the swampy pond on the Penataquit creek. It is reported that the amount of iron and the attendant growths in the water became so great as to fill the pipes and give the consumers much trouble. When the station was moved to its present site on comparatively high ground, ¾ mile northwest of the original location, no further difficulty occurred. There is a suspicion that this trouble came not so much from iron as from manganese, although no samples of scale from the old pipes have yet been obtained.

Much less attention has been given to manganese in ground-waters than to iron, and its determination is more difficult. A smaller amount of manganese is, perhaps, noticeable to the taste, and a supply should not contain, at the most, a larger amount than the greatest allowable percentage of iron. The weight of evidence, however, points to a still lower limit for the manganese.

ANNOYANCE TO SUFFOLK COUNTY RESIDENTS

Besides the advantages to be gained in the quality of the Suffolk County supply by placing the collecting works on comparatively high ground back from the south shore villages, this plan offers still another advantage quite as important as the others, in that the operation of the works on this location would disturb the ground-water surface but little in these villages and in the zone of settlement along the shore, and, therefore, would give little annoyance to the residents there.

If the line were placed well back, one-half mile to a mile north of the south shore villages, the lowering of the ground-water in the villages would not, under the most severe conditions of operation, probably amount to much over five feet, and would ordinarily be less, because the distance between the proposed collecting works and the south shore bays, or the large inlets from them, would be such that the rainfall on this strip south of the collecting works, would maintain there a water-table at least two feet above the mean sea, independent of any flow from the upland watershed. This water-table would, no doubt, furnish sufficient water for all but the more thickly populated parts of the largest villages, so that but few diversions of water need be made from the proposed collecting works to supply local needs.

This advantage of the location proposed is illustrated on Sheet 20, Acc. L 583, which exhibits two sections of the south shore of Suffolk county on a somewhat exaggerated vertical scale. It is evident, from a comparison of the two sections, that the Suffolk County residents need not fear the same annoyance from the operation of a line of collecting works well north of their villages as the people of the south shore towns in Nassau county have experienced.

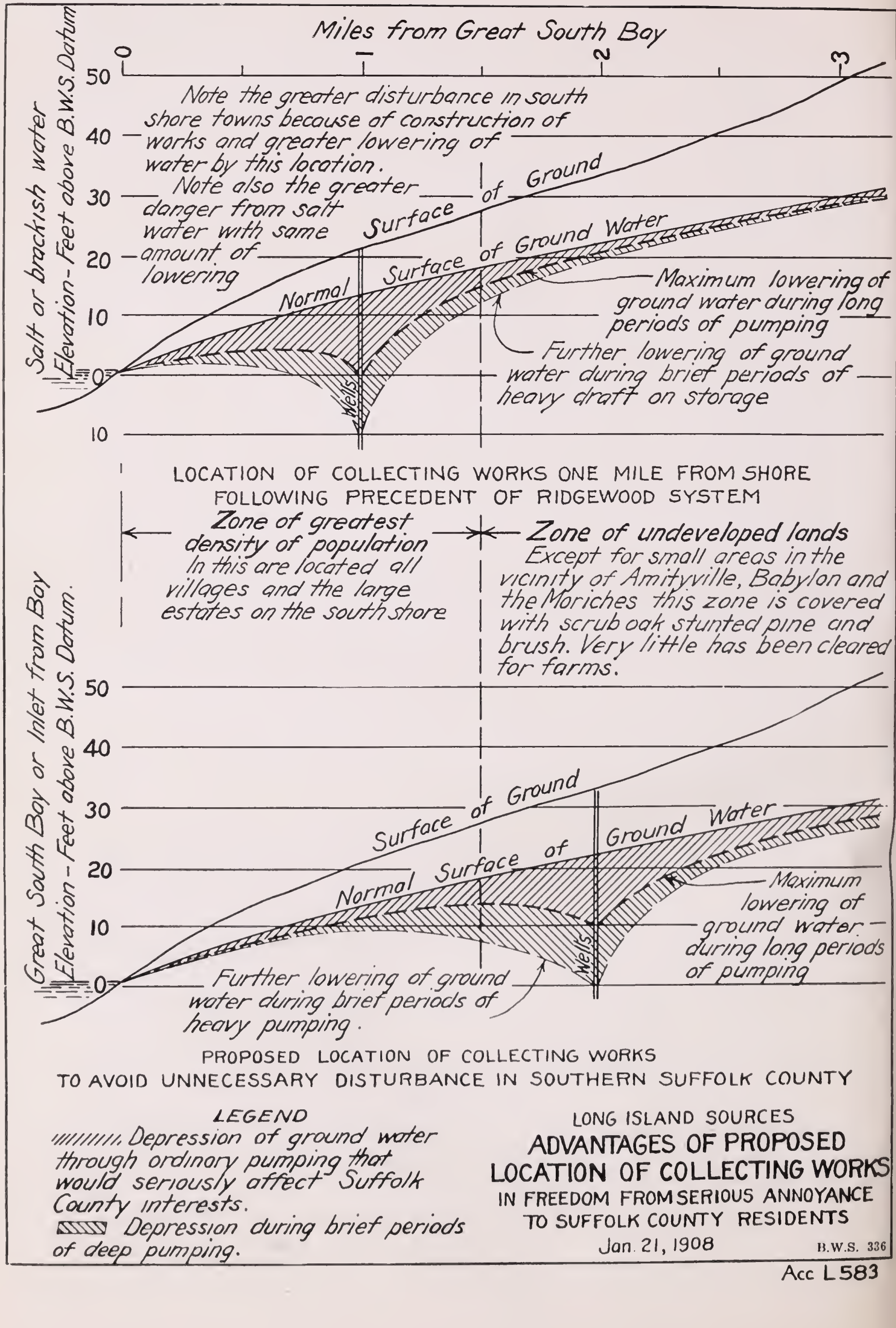
The depression in the surface of the ground-water resulting from the pumping on a location well back from these villages would not be noticeable beyond a distance of ½ mile from the works, and the lands within a zone ½ mile either side of this location are now covered, for the most part, with scrub oak, small pines and brush, as seen on Sheet 149, Acc. 5334, and on Plates 12 and 13 following this appendix. Even were there now, or likely to be in the future, many farms in this zone where the soil is, on the whole, very thin and poor, it is shown in Appendix 13 that the ground-water is generally so far below the ground surface that no water can be drawn up by capillarity for the uses of vegetation.

CONCLUSIONS ON LOCATION OF COLLECTING WORKS

The only advantage of a line as near the shore as the works of the Ridgewood system appears to be that of obtaining the maximum drainage area.

The loss of ground-water catchment in choosing a line well back from the shore need not, under average conditions of operation, be more than 10 per cent. of the whole area. The sacrifice of the small additional yield obtained would seem to be entirely justified by the insurance of a permanent supply of good water, free from the salts of sea-water, from the drainage of the towns and from high percentages of iron. By pumping deeply the wells on a location several miles from the shore, during brief periods of large demand, a counter slope might be established toward the wells that would, for a short time, make tributary to the higher line quite as large a drainage area as could safely be drawn upon by the works nearest the south shore.

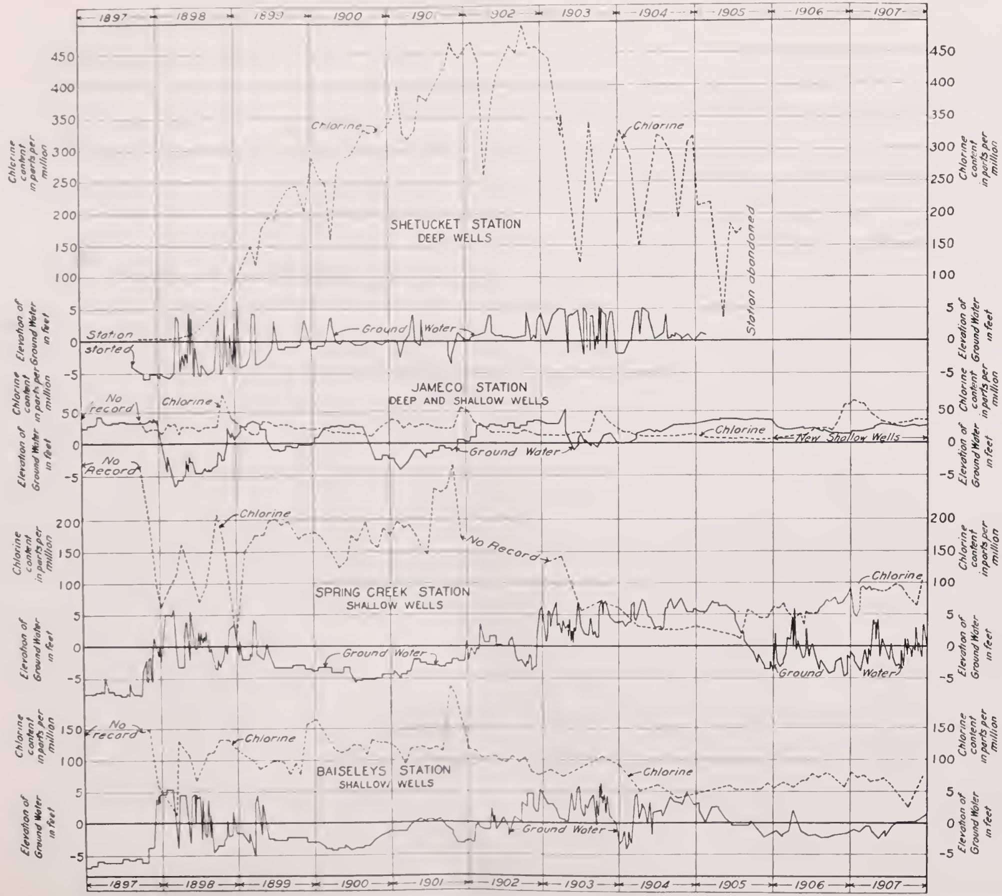
Another consideration that cannot be overlooked in choosing a location far from the shore, in the scrub oak country, is the advantage of cheaper land.


Miles from Great South Bay
0
1
2
3
Salt or brackish water
Elevation - Feet above B.W.S. Datum
50
40
30
20
10
0
10
Note the greater disturbance in south shore towns because of construction of works and greater lowering of water by this location.
Note also the greater danger from salt water with same amount of lowering
Surface of Ground
Normal Surface of Ground Water
Maximum lowering of ground water during long periods of pumping
Further lowering of ground water during brief periods of heavy draft on storage
Wells
LOCATION OF COLLECTING WORKS ONE MILE FROM SHORE
FOLLOWING PRECEDENT OF RIDGEWOOD SYSTEM
Zone of greatest density of population
In this are located all villages and the large estates on the south shore
Zone of undeveloped lands
Except for small areas in the vicinity of Amityville, Babylon and the Moriches this zone is covered with scrub oak stunted pine and brush. Very little has been cleared for farms.
Great South Bay or Inlet from Bay
Elevation - Feet above B.W.S. Datum.
50
40
30
20
10
0
Surface of Ground
Normal Surface of Ground Water
Maximum lowering of ground water during long periods of pumping
Further lowering of ground water during brief periods of heavy pumping.
Wells
PROPOSED LOCATION OF COLLECTING WORKS
TO AVOID UNNECESSARY DISTURBANCE IN SOUTHERN SUFFOLK COUNTY
LEGEND
Depression of ground water through ordinary pumping that would seriously affect Suffolk County interests.
Depression during brief periods of deep pumping.
LONG ISLAND SOURCES
ADVANTAGES OF PROPOSED LOCATION OF COLLECTING WORKS IN FREEDOM FROM SERIOUS ANNOYANCE TO SUFFOLK COUNTY RESIDENTS
Jan. 21, 1908
B.W.S. 336

The location now proposed for the collecting works in southern Suffolk county is one that provides the largest drainage area consistent with reasonable safety from the entrance of sea-water. It may be seen on Sheet 6, Acc. 5596, that this location fulfills the condition of being above the 20-foot ground-water contour, so far as economy in construction permits. The proposed line diverges southerly from this groundwater level at some points, to avoid excessive excavation in high ground, and again to shorten the aqueduct at river crossings. These points may be made reasonably safe by constructing fresh-water reservoirs in the larger streams below the works to exclude the salt water from the surface strata, as proposed in Appendix 9.

On Sheet 149, Acc. 5334, showing relation of cultivated areas and villages to the proposed line of collecting works, it may be observed that the works would be north of most of the south shore villages, and that the probable limit of inflection of the ground-water surface towards the works would be north of the more thickly populated areas. This map shows also that, but for the valleys of the largest Suffolk County streams, the collecting works avoid the low, swampy lands of the south shore.

The location of the collecting works must, of course, be made where the water bearing strata are most favorable for the collection of a supply. The borings have shown more coarse material in the direction of the center of the island than near the south shore, and this fact is still another argument for the scrub oak location.



Ground water level determined from daily measurements in test wells.

Where three test wells were used, double weight was given to the center well in determining elevation of water at station.

Water levels as plotted show elevation at beginning and end of periods of fluctuation, and averages where fluctuations were less than 0.5 feet.

At SHETUCKET STATION, average of three wells taken from 1897 to Jan. 14, 1899. One well used after Jan. 14, 1899.

At JAMECO STATION, the supply from 1897 to 1906 was drawn from both shallow and deep wells. The water level was measured in test wells along line of shallow wells, and from one to three wells were used to determine the elevation of water. During 1906 and 1907 the same test wells were used, but the supply was drawn from new shallow wells driven from 150 feet to 350 feet from the test wells.

At SPRING CREEK STATION the elevation of water was determined by three test wells driven at the center, east and west end of the old service wells. The chlorine content as plotted was determined by the water drawn from these wells up to 1903. During the five years from 1903 to 1907, the waters of the old and temporary shallow wells were mixed except from Nov. 1906 to Mar. 1907.

At BAISELEYS STATION, three test wells along the line of service wells were used, except from Aug. 1 to Nov. 1, and Dec. 1 to Dec. 17, 1902, when the center test well was used.

Zero as given refers to elevation of ground water and also chlorine content.

Elevation 5 feet is equivalent to 50 parts of chlorine per million.

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
GROUND WATER LEVEL AND CHLORINE CONTENT
AT
DRIVEN WELL STATIONS AFFECTED BY SALT WATER
RIDGEWOOD SYSTEM
From Records of the Department of Water Supply
From 1897 to 1907
FEBRUARY 25 1908

PLATE 12

Typical sproutland between Lindenhurst and Babylon.

Typical scrub oak and pine barrens between Islip and Oakdale.

APPENDIX 3

GENERAL PLAN FOR SUFFOLK COUNTY COLLECTING WORKS

BY WALTER E. SPEAR, DIVISION ENGINEER

So far as may be consistent with the greatest possible development of Suffolk County waters, the method of collecting should, in general, be one that offers the greatest economy in construction and operation, with the least disturbance to local interests and with no impairment of the quality of the supply. The design of the collecting works to meet these conditions must depend primarily upon the character, depth and distribution of the water bearing gravels, and upon the strata that separate them from the source of all water-supply, the rains that fall upon the surface of the island.

The deep strata in Suffolk county have been thoroughly investigated by deep test-wells during the past year. The results of the borings are given in Table 15, pages 224 to 255, and in the large scale sections, Sheets 46, 47, 48 and 49, Accs. 5592, 5595, 5593 and 5594.

The large stovepipe wells driven by the Board of Water Supply from which most of these data were obtained, provide the most accurate samples of the strata penetrated, because the material is brought to the surface in large masses by the sand buckets, 10 to 12 inches in diameter, without the separation of the coarse and the fine particles that takes place in wash borings, and samples of strata are secured with even greater certainty than by dry sampling in smaller wells. The 2-inch test-borings give less accurate samples, but they confirm in general the results from the larger wells.

It would be interesting to have learned the total depth of the unconsolidated sands in southern Suffolk county, but there was little likelihood of finding any considerable supply of water beyond 400 or 500 feet in depth, and only two borings of greater depth than this were made. One near Brookhaven reached a depth of 940 feet and stopped in superfine sand and gravel. Among these tables are given the log of a test-well driven by wash boring methods by the Department of Water Supply at Seaford, Table 15, page 224. This well was driven

to a depth of 1050 feet without striking bed-rock, so that these sand and gravel strata on the south shore in Suffolk county may have a thickness of 1100 or 1200 feet.

WATER BEARING STRATA

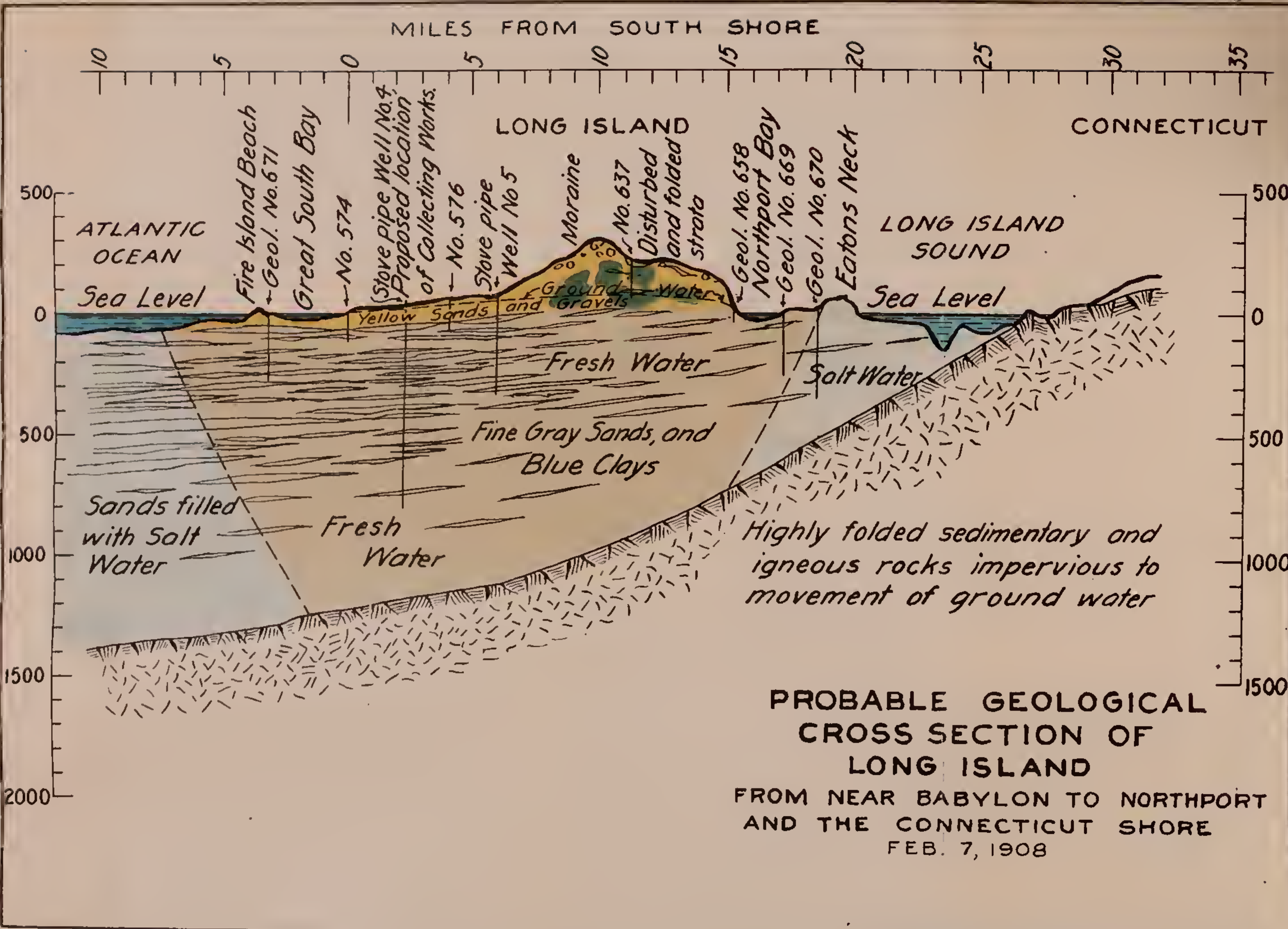
The principal water horizons recognized in southern Long Island are the upper or yellow glacial gravels, and the deep gray gravels of cretaceous origin. Only the yellow gravels are of importance in a large development of ground-water in southern Suffolk county. The general location of the yellow gravels and their relation to the much deeper beds of gray sands and clays in which the gray gravels occur, are shown in the cross-section of Suffolk county, Sheet 22, Acc. L 601.

This section is typical of eastern Long Island, which differs somewhat from the extreme westerly end, where there are surface outcrops of the consolidated bed-rocks which, in Suffolk county, are probably 600 to 1100 feet or more below the surface.

Yellow Gravels

The yellow quartz gravels which owe their distinctive color to their coating of iron oxide, make up the upper strata in Long Island, and except in a few localities, entirely cover the gray sands and clays beneath. The longitudinal section of southern Long Island, Sheet 23, Acc. L 602, shows that these yellow sands and gravels have a depth of 80 to 200 feet, and that these beds are, on the whole, thicker in Suffolk county than in western Long Island.

From this diagram and the large scale sections, Sheets 46, 48 and 49, Accs. 5592, 5593 and 5594, it appears that not only are the yellow gravels in Suffolk county of greater depth, but they are quite as coarse as those in Nassau and Queens counties, from which the greater part of the waters of the Ridgewood supply is drawn, and the Suffolk County strata are, therefore, more favorable for the development of a large ground-water supply than the same strata in western Long Island. There is no evidence in the Suffolk County borings to show that there are any impervious beds of clay in the yellow gravel strata, yet it is important in considering the designs for the proposed collecting works to note that there are layers of fine and medium sand here and there that must in some measure interrupt the free vertical movement of the ground-water.

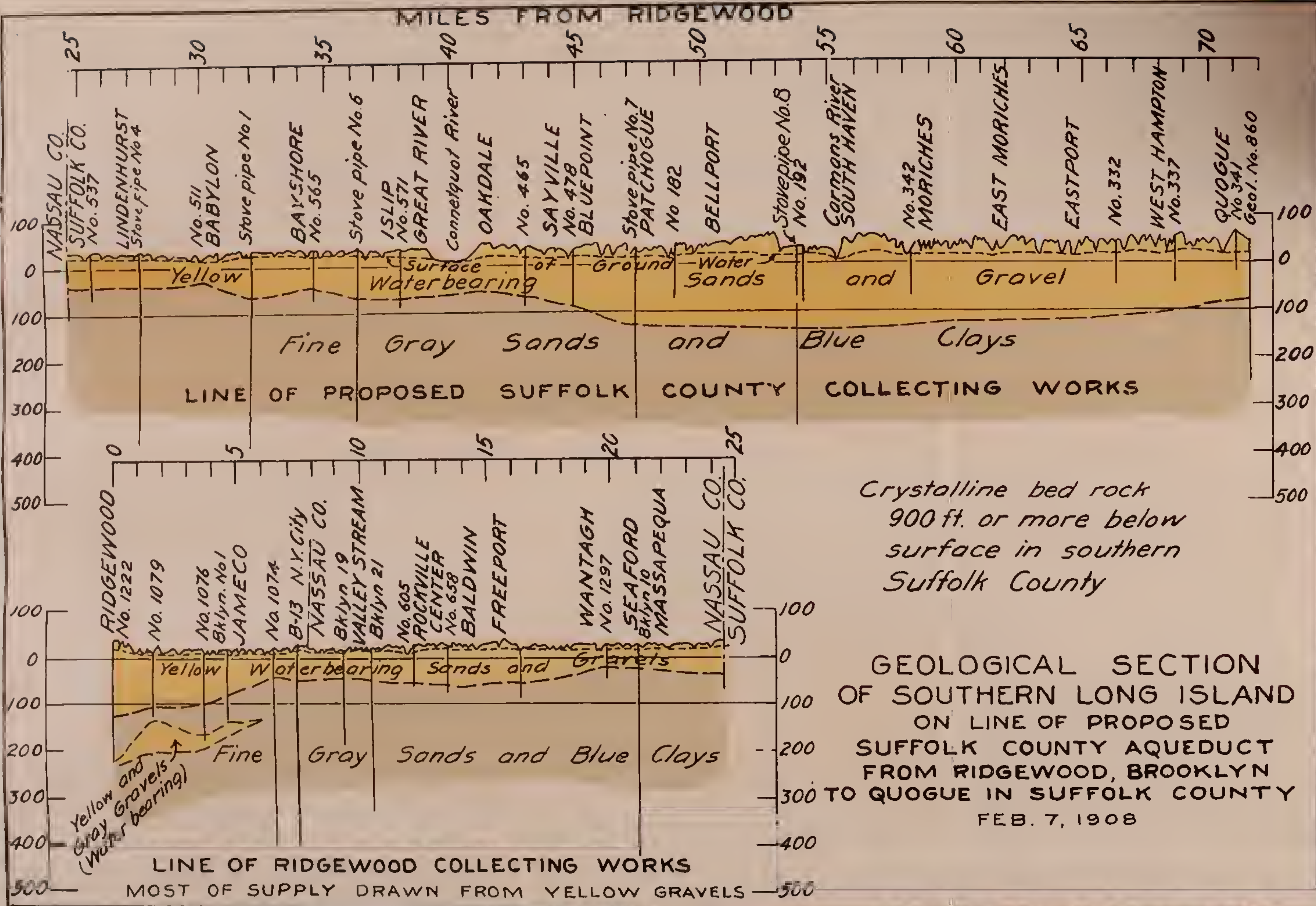


PROBABLE GEOLOGICAL CROSS SECTION OF LONG ISLAND

FROM NEAR BABYLON TO NORTHPORT AND THE CONNECTICUT SHORE

FEB. 7, 1908

M. B. BROWN PRINTING & BINDING CO., N. Y.



GEOLOGICAL SECTION
OF SOUTHERN LONG ISLAND
ON LINE OF PROPOSED
SUFFOLK COUNTY AQUEDUCT
FROM RIDGEWOOD, BROOKLYN
TO QUOGUE IN SUFFOLK COUNTY
FEB. 7, 1908

M. B. BROWN PRINTING & BINDING CO. N. Y.

Table 12 shows the mechanical analyses of the yellow sands and gravels taken from the large stovepipe wells that have been driven along the line of the proposed collecting works. This table gives the effective size and uniformity coefficients of the coarse water bearing strata and of the finer sands that separate them. The effective size of the coarse material that would be drawn upon by a well system ranges from 0.3 to 10.0 millimeters with fairly large uniformity coefficients, indicative of the gravel which they contain. The finest of the yellow sands in these wells have an effective size of 0.2 millimeter, and these are generally uniform and therefore pervious.

It is interesting to compare these sands with water bearing strata from which other ground-water supplies are drawn:

Sample	Effective Size Millimeter	Uniformity Coefficients
El Monte well near Los Angeles, Cal.	0.17	7.1
Burbank wells of Los Angeles water-works	0.20	6.5
Erlenstegen wells, Nuremberg works	0.35	2.3
Dune sands near Amsterdam	0.18	1.4

The finer strata in the yellow gravels of southern Suffolk county are as favorable for the general movement of the ground-water as any of these materials from the California wells or from those abroad. There appears to be no reason why some form of well may not be designed to collect water from any or all of the yellow gravels that have been found in these borings.

The sands from the two stovepipe wells near Los Angeles, represent strata opposite which perforations were to be made in these casings to admit the supply. As indicated by the large uniformity coefficients, there was sufficient gravel mixed with the finer sands to form a filter about the well. It is interesting to note that the El Monte well, which was 14 inches in diameter, 1020 feet deep, and perforated for 324 feet of its length, yielded three million gallons per day. The wells of the Nuremberg works (see Sheet 32, Acc. L 81) were placed in the material here shown. The supply from the dune works of Amsterdam is collected in open canals, but The Hague supply is drawn from infiltration galleries in the same material.

The transverse section, Sheet 47, Acc. 5595, brings out the

interesting fact that the yellow gravels are coarser in the center of the island than on the line where it is proposed to collect the supply, and that these beds are still finer close to the south shore. This is but to be expected, as the material was deposited by southerly flowing water from the face of the glacier, and the coarser material was naturally dropped first and the finer material carried further seaward. The coarse soils and substrata of the center of the island make these outwash plains an exceedingly favorable collecting ground, and the deposition of the finer material near the shore protects, to some extent, the proposed collecting works from the entrance of brackish water from the south shore bays.

Gray Gravels

The great mass of unconsolidated material underlying the yellow gravels throughout Long Island is made up of fine gray and white sands and black clays. Much lignite and iron sulphide are found at all depths. Some of the gray sands are not much finer than the finest of the yellow sands above them and are generally more uniform. The coarser gray sands have an effective size of 0.25 to 0.35 millimeter and a uniformity coefficient from one to two, but all contain more or less clay with which they are interbedded, and it was found that this clay cuts down the rate of ground-water movement through them. The many thick beds of clay with which the gray sands are interstratified prevent the free movement of water in a vertical direction and interfere with the supply of rain-water from the surface. These gray sands are too fine for the screen of an ordinary well and there is no gravel in them as in the yellow gravels to form a natural filter to exclude the finer material. They cannot, therefore, be considered as water bearing in the sense that they would readily give up their water, although they would doubtless yield a small amount of water if wells having fine strainers of the Cook or Johnson type were driven in them. The depth of the gray sands is such, however, that the development of the water in them would be expensive and quite unnecessary, as the proposed supply can be intercepted more economically in the yellow gravels.

The borings thus far made in southern Suffolk county have not revealed any beds of coarse water bearing gravel in these gray sands, although the larger wells were driven to depths

TABLE 12

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 1, Experiment Station, West Islip, Long Island, 14 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 33.4; Ground-water, 23.9

Sample No.	Depth Below Surface Feet: From	Depth Below Surface Feet: To	Kind of Sampling	Character of Material	Color	Mechanical Analysis: Effective Size	Mechanical Analysis: Uniformity Coefficient
1	0	3	Dry	Sandy loam	Light brown	0.35	2.28
2	3	9	"	Coarse and fine gravel; coarse sand	" "	0.47	4.68
3	9	12	Sand bucket	Coarse gravel; coarse sand	White and yellowish brown	0.73	39.70
4	12	17	" "	Coarse and fine gravel; coarse sand		0.51	21.56
5	17	26	" "	Coarse and fine gravel; coarse sand	Brownish yellow	0.66	23.18
7	26	38	" "	Coarse, medium and fine sand	" "	0.29	1.75
8	38	54	" "	Gravel; medium and fine sand	" "	0.33	1.85
9	54	60	" "	" " " " "	" "	0.28	2.00
10	60	70	" "	Medium sand	White and light yellow	0.36	1.36
11	70	75	" "	Coarse, medium and fine sand	Brownish yellow	0.35	1.48
12	75	80	" "	Medium and fine sand	White and light yellow	0.31	1.55
13	80	88	" "	Gravel; coarse and medium sand; organic matter	Dark brown	0.36	2.22
14	88	94	" "	Coarse and fine gravel; sand	Brownish yellow	0.39	23.07
15	94	97	" "	Coarse and fine gravel; coarse sand	" "	1.30	5.23
16	97	98	" "	Coarse and fine gravel; coarse sand	" "	2.20	13.60

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 2, Experiment Station, West Islip, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 30; Ground-water, 23.9

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
1	0	3.6	Dry	Gravelly loam	Yellowish brown	0.43	3.72
2	3.6	4.5	"	Clay; sand	Blue-gray	*0.51	
3	4.5	6.6	"	Fine gravel; coarse and medium sand	Yellowish brown	0.59	6.61
4	6.6	7.1	"	Fine gravel; coarse and medium sand	" "	0.60	4.66
5A	7.1	10	"	Coarse and medium sand	Brownish yellow	0.45	2.44
5B	10	12	Sand bucket	Coarse gravel	" "	10.5	2.66
6	12	13	" "	Coarse and fine gravel; coarse sand	" "	1.35	12.22
7	13	16	" "	Coarse, medium and fine sand	" "	0.33	1.78
8	16	17	" "	Coarse and fine gravel; coarse sand	" "	1.80	5.27
9	17	18	" "	Coarse and fine gravel; coarse sand	" "	0.90	3.60
10	18	19.5	" "	Coarse and fine gravel; coarse sand	" "	0.63	12.3
11	19.5	21	" "	Coarse and fine gravel; coarse sand	" "	0.54	4.81
12	21	23.2	" "	Coarse, medium and fine sand	" "	0.32	1.65
13	23.2	25.2	" "	Gravel; coarse and fine sand	" "	0.37	2.38
14	25.2	26.9	" "	Fine gravel; coarse and medium sand	" "	0.37	4.05
15	26	29	" "	Coarse, medium and fine sand	" "	0.34	1.76
16	29	30	" "	Coarse and medium sand	" "	0.40	1.87
17	30	33	" "	Coarse, medium and fine sand	" "	0.32	1.56
18	33	38	" "	" " " " "	" "	0.28	1.78
19	38	42	" "	" " " " "	" "	0.30	1.73
20	42	46	" "	" " " " "	" "	0.29	1.72
21	46	48	" "	" " " " "	" "	0.29	1.75
22	48	50	" "	Fine gravel; coarse, medium and fine sand	" "	0.32	2.18
23	50	52	" "	Fine gravel; coarse, medium and fine sand	" "	0.30	2.50
24	52	54.5	" "	Coarse, medium and fine sand	" "	0.28	1.71
25	54.5	56	" "	Coarse and medium sand	" "	0.36	2.22
26	56	58	" "	Medium and fine sand	" "	0.25	1.68
27	58	62	" "	" " " "	" "	0.30	1.60
28	62	64	" "	" " " "	" "	0.22	1.63
29	64	66.5	" "	" " " "	" "	0.26	1.65
30	66.5	68	" "	" " " "	" "	0.23	1.78
31	68	70	" "	" " " "	Light yellow	0.23	1.69
32	70	72.6	" "	" " " "	" "	0.26	1.57
33	72.6	74	" "	" " " "	Brownish yellow	0.19	2.00
34	74	78.3	" "	Fine gravel; medium and fine sand	" "	0.19	2.00
35	78.3	80	" "	Medium and fine sand	" "	0.22	1.77
37	82	84	" "	" " " "	" "	0.19	1.94
38	84	86	" "	" " " "	" "	0.18	2.05
39A	86	88	" "	Coarse and fine gravel; sand	Rich yellow	0.60	18.33
39B	86	88	" "	Sandstone; pyrites; gravel	Dark brown	....	....
40	88	89.5	" "	" clay	Blue, gray and dark brown	..	....
41	89.5	91	" "	Coarse and fine gravel	Brownish yellow	2.9	7.58

*60 per cent. finer than

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 3, Experiment Station, West Islip, Long Island, 16 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 30; Ground-water, 23.9

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
1	0	2	Dry........	Gravelly loam..............	Light brown....	0.37	2.97
2	2	4	"	Clay; coarse and medium sand; gravel....................	Brownish gray..	0.31	4.84
3	4	6	"	Coarse and fine gravel; coarse sand....................	Yellowish brown.	0.55	4.18
4	6	12	"	Fine gravel; coarse sand......	White and light yellow........	0.68	2.50
5	12	13	Sand bucket.	Coarse and fine gravel; coarse sand....................	White and light yellow.......	2.0	11.5
6	13	15.5	" "	Coarse and fine gravel; coarse sand....................	White and light yellow.......	1.5	16.0
7	13	15.5	" "	Coarse and fine gravel; coarse sand....................	White and light yellow........	1.1	11.8
8	15.5	17	" "	Coarse and fine gravel; coarse sand....................	White and light yellow.......	1.1	16.36
9	15.5	17	" "	Coarse and fine gravel; coarse sand....................	White and light yellow.......	0.85	19.4
10	17	19	" "	Coarse and fine gravel; coarse sand....................	White and light yellow.......	2.0	6.50
11	19	21	" "	Coarse and fine gravel; coarse and medium sand.........	White and light yellow.......	0.50	38.0
12	21	23	" "	Coarse and fine gravel; sand..	White and light yellow.......	0.62	32.2
13	23	25	" "	Coarse and fine gravel; coarse sand....................	White and light yellow.......	0.51	25.5
14	25	27	" "	Coarse and fine gravel; coarse sand....................	White and light yellow.......	0.60	30.8
15	27	29	" "	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.42	2.40
16	29	31	" "	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.47	5.95
17	31	33	" "	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.52	32.6
18	33	35	" "	Coarse gravel; coarse and medium sand...............	Brownish yellow.	0.37	35.1
19	35	37	" "	Coarse gravel; coarse and medium sand............	" "	0.36	2.11
20	37	39	" "	Coarse and fine gravel; coarse and medium sand.........	" "	0.42	8.09
21	39	41	" "	Coarse gravel; coarse and medium sand............	" "	0.37	2.46
22	41	43	" "	Coarse gravel; coarse and medium sand............	" "	0.35	2.57
23	43	45	" "	Coarse gravel; coarse, medium and fine sand............	" "	0.35	1.97
24	45	49	" "	Coarse gravel; coarse, medium and fine sand............	" "	0.34	2.23
25	49	51	" "	Coarse gravel; coarse medium and fine sand	" "	0.33	1.93
26	51	53	" "	Coarse, medium and fine sand.	" "	0.29	1.89
27	53	55	" "	" " " " "	" "	0.35	1.88
28	55	57	" "	" " " " "	" "	0.26	1.84
29	57	59	" "	" " " " "	" "	0.29	1.76
30	59	61	" "	" " " " "	" "	0.32	1.53
31	61	63	" "	Medium and fine sand......	" "	0.23	1.78
32	63	65	" "	" " " "	" "	0.26	1.57
33	65	67	" "	" " " "	" "	0.27	1.78
34	67	69	" "	" " " "	" "	0.28	1.50
35	69	71	" "	" " " "	" "	0.26	1.54
36	71	73	" "	" " " "	" "	0.34	1.26
37	73	75	" "	" " " "	" "	0.24	1.70
38	75	77	" "	" " " "	" "	0.23	1.78
39	77	79	" "	" " " "	" "	0.22	1.68
40	79	81	" "	" " " "	" "	0.26	1.61
41	81	83	" "	" " " "	" "	0.27	1.50
42	83	86	" "	" " " "	" "	0.27	1.55
43	86	87	" "	Coarse and fine gravel; coarse and medium sand.........	Light brown....	0.35	19.1
44	87	89	" "	Coarse gravel; coarse and medium sand............	" "	0.37	25.4
45	89	91	" "	Coarse gravel; coarse and medium sand............	" "	0.57	23.4
46	91	93	" "	Coarse and fine gravel; sand..	" "	0.65	40.0
47	93	95	" "	Coarse gravel; coarse and medium sand............	" "	0.37	2.42
48	95	97	" "	Medium and fine sand......	Brownish yellow.	0.31	1.54
49	97	99	" "	" " " "	" "	0.27	1.52
50	99	101	" "	" " " "	" "	0.32	1.47

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 4, Experiment Station, Lindenhurst, Long Island, 14 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 30; Ground-water, 22.3

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
1	0	2½	Sand bucket.	Loam; sand; vegetable matter.	Brown.........	0.31	2.00
2	2½	5	" "	Gravelly loam...............	"	0.37	4.32
3	5	6	" "	Coarse, medium and fine sand.	Yellow.........	0.24	2.17
4	6	9	" "	" " " " "	White and light yellow.......	0.37	3.78
5	9	11	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.34	3.82
6	11	13	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.39	5.41
7	13	15	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.35	6.28
8	15	17	" "	Coarse gravel and coarse sand..	White and light yellow.......	0.60	35.00
9	17	19	" "	Gravel and medium sand.....	White and light yellow.......	0.43	13.25
10	19	21	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.86	30.20
11	21	23	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.79	34.2
12	23	25	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.93	6.88
13	25	27	" "	Coarse and fine gravel; coarse sand.....................	Brownish yellow.	0.55	4.91
14	27	29	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.51	11.70
15	29	31	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.78	11.30
16	31	33	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.43	34.90
17	33	35	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.40	5.25
18	35	37	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.36	2.61
19	37	39	" "	Gravel; coarse and medium sand.....................	White and light yellow........	0.38	10.00
20	39	41	" "	Coarse, medium and fine sand.	White and light yellow.......	0.35	2.11
21	41	45	" "	" " " " "	Yellow, white and light yellow...	0.34	2.56
22	45	47	" "	Coarse and fine gravel.......	Yellow, white and light yellow...	0.66	13.50
23	47	49	" "	Gravel; coarse and fine sand..	Yellow, white and light yellow...	0.38	2.13
24	49	51	" "	Medium and fine sand.......	Yellow, white and light yellow...	0.32	1.62
25	51	53	" "	Gravel; coarse and medium sand.....................	Yellow, white and light yellow...	0.46	2.30
26	53	55	" "	Gravel; coarse and medium sand.....................	Yellow, white and light yellow...	0.37	3.83
27	55	57	" "	Coarse and medium sand......	Yellow, white and light yellow...	0.32	2.03
28	57	59	" "	Coarse and fine gravel; coarse sand.....................	Yellow, white and light yellow...	0.57	2.19
29	59	61	" "	Coarse and fine gravel; coarse sand.....................	Yellow, white and light yellow...	0.42	2.74

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 5 at Experiment Station, Wyandanch, Long Island, 12 Inches in Diameter. Elevation, B.W. S. Datum: Surface of Ground, 56; Ground-water, 51

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
1	0	1	Sand bucket.	Loam and gravel	Brown	0.52	10.00
2	1	4	" "	Coarse and fine gravel	Brownish yellow.	0.76	36.00
3	4	6	" "	Coarse and fine gravel; coarse sand	" "	0.36	6.11
4	6	10	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.42	6.78
5	10	15	" "	Gravel; coarse and medium sand	White and light yellow	0.49	4.08
6	15	18	" "	Gravel; coarse and medium sand	White and light yellow	0.365	11.40
7	18	20	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.62	12.40
8	20	22	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.52	9.88
9	22	24	" "	Coarse and fine gravel; medium sand	White and light yellow	0.45	32.90
10	24	26	" "	Coarse and fine gravel; medium sand	White and light yellow	0.41	15.10
11	26	28	" "	Gravel; coarse and medium sand	White and light yellow	0.35	2.14
12	28	30	" "	Coarse and fine gravel; medium sand	White and light yellow	0.37	13.50
13	30	32	" "	Coarse and fine gravel; medium sand	White and light yellow	0.415	13.80
14	32	34	" "	Coarse gravel; medium sand	White and light yellow	0.41	34.10
15	34	36	" "	Coarse and fine gravel; medium sand	White and light yellow	0.40	35.00
16	36	38	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.39	10.50
17	38	40	" "	Coarse and fine gravel; sand	White and light yellow	1.60	17.50
18	40	42	" "	" " " " "	White and light yellow	0.41	20.20
19	42	44	" "	Gravel; coarse and medium sand	White and light yellow	0.38	4.47
20	44	46	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.41	31.70
21	46	48	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.38	8.97
22	48	50	" "	Coarse and fine gravel; sand	White and light yellow	0.44	18.00
23	50	52	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.51	2.55
24	52	54	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.425	31.70
25	54	56	" "	Gravel; coarse and medium sand	White and light yellow	0.40	10.00
26	56	58	" "	Gravel; coarse and medium sand	White and light yellow	0.35	4.57
27	58	60	" "	Coarse and fine gravel; sand	White and light yellow	0.73	35.30
28	60	62	" "	Coarse and fine gravel	White and light yellow	8.7	3.39
29	62	64	" "	" " " " clay	Brownish yellow.	6.1	4.00
30	64	66	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.37	5.24
31	66	68	" "	Coarse and fine gravel; coarse sand	White and light yellow	0.57	5.61
32	68	70	" "	Coarse and fine gravel; clay	Light gray	0.125	2.16
33	70	72	" "	Coarse and medium sand; clay.	" "	0.16	2.88
34	72	74	" "	Gravel; coarse and medium sand	Yellowish gray	0.40	6.00

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 6, Corner Grand Boulevard and 44th Street, North of Islip, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 37.5; Ground-Water, 24.8

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
1	0	3	Sand bucket.	Sandy loam	Light brown	0.26	2.08
2	3	5	" "	Coarse and medium sand	" "	0.33	2.00
3	5	7	" "	Coarse, medium and fine sand.	" yellow	0.34	1.62
4	7	10	" "	Coarse and fine gravel; sand	" "	0.40	33.75
5	10	14	" "	Gravel; coarse and medium sand	" "	0.30	2.03
6	14	17	" "	Coarse and fine gravel; coarse sand	" "	0.58	6.03
7	17	20	" "	Gravel; coarse and medium sand	" "	0.32	5.62
8	20	22	" "	Coarse and fine gravel; coarse sand	" "	0.41	5.61
9	22	24	" "	Gravel; coarse and medium sand	" "	0.34	2.35
10	24	26	" "	Gravel; coarse and medium sand	Yellow	0.34	2.65
11	26	28	" "	Gravel; coarse and medium sand	"	0.32	1.81
12	28	30	" "	Coarse, fine and medium sand.	"	0.34	1.85
13	30	32	" "	" " " " "	"	0.33	1.67
14	32	34	" "	Coarse gravel; coarse and medium sand	"	0.35	2.51
15	34	36	" "	Gravel; coarse and medium sand	"	0.37	2.97
16	36	38	" "	Coarse and medium sand	"	0.36	1.58
17	38	40	" "	Coarse, medium and fine sand.	"	0.35	2.11
18	40	42	" "	Gravel; coarse and medium sand	"	0.36	1.89
19	42	44	" "	Gravel; coarse and medium sand	"	0.33	2.18
20	44	46	" "	Coarse, medium and fine sand.	"	0.34	1.74
21	46	48	" "	Gravel; coarse and medium sand	"	0.36	1.78
22	48	50	" "	Coarse, medium and fine sand.	Rich yellow	0.32	1.66
23	50	52	" "	" " " " "	" "	0.34	1.56
24	52	54	" "	" " " " "	" "	0.24	1.79
25	54	56	" "	Gravel; coarse, medium and fine sand	Dark yellow	0.33	1.70
26	56	58	" "	Medium and fine sand	" "	0.28	1.64
27	58	60	" "	" " " "	Dark brown	0.18	2.06
28	60	62	" "	Coarse, medium and fine sand.	Light brown	0.25	1.88
29	62	64	" "	" " " " "	Dark brown	0.26	1.85
30	64	68	" "	Medium and fine sand	" "	0.28	1.64
31	68	70	" "	Coarse, medium and fine sand.	" "	0.34	1.35
32	70	72	" "	Medium and fine sand	Dark yellow	0.24	1.20
33	72	74	" "	" " " "	" "	0.25	1.68
34	74	76	" "	" " " "	" "	0.25	1.64
35	76	78	" "	" " " "	" "	0.24	1.79
36	78	80	" "	Coarse, medium and fine sand.	" "	0.27	1.74
37	80	82	" "	" " " " "	" "	0.31	1.77
38	82	84	" "	Medium and fine sand	" "	0.24	1.75
39	84	86	" "	Gravel; coarse, medium and fine sand	" "	0.29	2.00
40	86	88	" "	Coarse, medium and fine sand.	" "	0.24	2.79
41	88	90	" "	" " " " "	" "	0.24	1.96
42	90	92	" "	Gravel; coarse, medium and fine sand	" "	0.27	1.96
43	92	94	" "	Coarse, medium and fine sand.	" "	0.30	1.90
44	94	96	" "	" " " " "	" "	0.32	1.53
45	96	98	" "	" " " " "	" "	0.34	1.62
46	98	100	" "	Coarse gravel; medium and fine sand	" "	0.28	1.96
47	100	102	" "	Coarse, medium and fine sand.	" "	0.28	1.79
48	102	104	" "	Medium and fine sand	" "	0.25	1.68
49	104	106	" "	Coarse, medium and fine sand.	Dark brown	0.28	1.71
50	106	108	" "	Medium and fine sand	" "	0.28	1.79
51	108	110	" "	Coarse gravel; medium and fine sand	" "	0.19	2.21

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 7, North of Patchogue, and Easterly Side of Patchogue Lake, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 25.7; Ground-water, 18.2

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
1	0	1.5	Sand bucket.	Sandy loam.	Light brown	0.32	1.97
2	1.5	5	" "	" "	" "	0.33	2.27
3	5	8	" "	Coarse, medium and fine sand.	Light yellow	0.30	1.67
4	8	11	" "	" " " " "	" "	0.32	1.78
5	11	15	" "	Gravel; coarse and medium sand	" "	0.37	1.89
6	15	19	" "	Coarse gravel; coarse and medium sand	" "	0.375	2.24
7	19	23	" "	Coarse gravel; coarse and medium sand	" "	0.35	2.28
8	23	27	" "	Coarse, medium and fine sand.	" "	0.335	1.82
9	27	32	" "	" " " " "	" "	0.32	1.69
10	32	35	" "	Coarse gravel; coarse and medium sand	" "	0.35	2.48
11	35	40	" "	Coarse, medium and fine sand.	" "	0.35	1.77
12	40	44	" "	" " " " "	Brownish yellow.	0.29	1.79
13	44	47	" "	" " " " "	" "	0.28	1.78
14	47	51	" "	" " " " "	" "	0.28	1.86
15	51	55	" "	" " " " "	" "	0.32	1.75
16	55	59	" "	" " " " "	" "	0.28	2.00
17	59	63	" "	" " " " "	" "	0.255	2.08
18	63	67	" "	" " " " "	" "	0.24	1.96
19	67	71	" "	" " " " "	" "	0.255	1.80
20	71	75	" "	" " " " "	" "	0.28	2.28
21	75	79	" "	" " " " "	" "	0.32	1.75
22	79	83	" "	" " " " "	" "	0.32	1.75
23	83	87	" "	Medium and fine sand	" "	0.205	1.80
24	87	91	" "	Medium and fine mica's sand.	Light brown	0.19	1.97
25	91	95	" "	" " " " "	" "	0.18	2.14
26	95	99	" "	" " " " "	Light yellow	0.18	2.33
27	99	103	" "	" " " " "	" "	0.21	1.93
28	103	107	" "	" " " " "	" "	0.225	1.82
29	107	111	" "	" " " " "	Rich yellow	0.225	1.77
30	111	117	" "	" " " " "	" "	0.23	1.74
31	117	121	" "	" " " " "	" "	0.13	2.31
32	121	125	" "	" " " " "	Brownish yellow.	0.12	4.00
33	125	129	" "	Medium, fine and superfine micaceous sand	" "	0.10	3.30
34	129	133	" "	Medium, fine and superfine micaceous sand	" "	0.15	2.77
35	133	137	" "	Coarse, medium and fine sand.	" "	0.25	2.20
36	137	141	" "	Coarse and medium sand	" "	0.37	1.89
37	141	145	" "	" " " "	" "	0.42	1.89
38	145	149	" "	" " " "	" "	0.39	1.79
39	149	153	" "	Coarse gravel; coarse and medium sand	" "	0.42	2.21
40	153	157	" "	Coarse gravel; coarse, medium and fine sand	" "	0.26	3.11
41	157	161	" "	Fine and superfine sand and clay	Brownish black.	*0.25	
42	161	167	" "	Coarse, medium and fine sand.	Dark brown	0.20	2.70
43	167	170	" "	Hard clay	Black	....	....
44	170	174	" "	Coarse, medium and fine sand.	Dark yellow	0.26	2.27
45	174	176	" "	" " " " "	Light yellow	0.165	3.09

*60 per cent. finer than

TABLE 12 (*Continued*)

MECHANICAL ANALYSIS AND CLASSIFICATION

California Stovepipe Well 8, at Road Intersections One Mile North of Brookhaven Railroad Station, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 35.5; Ground-water, 22.7

Sample No.	Depth Below Surface Feet From	Depth Below Surface Feet To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Mechanical Analysis Uniformity Coefficient
1	0	2	Dry........	Gravelly loam...............	Light brown....	0.16	6.25
2	2	3	"	Clay.........................	Light yellow....		*0.13
3	3	4	"	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.54	25.93
4	4	8	"	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.43	2.09
5	8	12	Sand bucket.	Coarse and medium sand.....	White and light yellow.......	0.42	1.81
6	12	15	" "	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.43	2.79
7	15	18	" "	Coarse, medium and fine sand.	White and light yellow.......	0.33	2.24
8	18	22	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.39	3.08
9	22	26	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.64	43.75
10	26	30	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.36	1.89
11	30	34	" "	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.39	123.00
12	34	38	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.78	26.92
13	38	42	" "	Coarse, medium and fine sand.	White and light yellow.......	0.32	1.92
14	42	46	" "	Coarse gravel; medium sand..	White and light yellow.......	0.42	66.7
15	46	50	" "	Coarse, medium and fine sand.	White and light yellow.......	0.34	1.88
16	50	54	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.36	2.14
17	54	58	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.35	2.77
18	58	62	" "	Gravel; coarse and medium sand.....................	White and light yellow.......	0.37	2.43
19	62	66	" "	Gravel; coarse, medium and fine sand................	White and light yellow.......	0.28	2.14
20	66	70	" "	Coarse, medium and fine sand.	White and light yellow.......	0.24	1.88
21	70	74	" "	" " " " "	White and light yellow.......	0.28	2.00
22	74	76	" "	" " " " "	White and light yellow.......	0.24	2.00
23	76	80	" "	" " " " "	White and light yellow.......	0.26	1.92
24	80	84	" "	" " " " "	White and light yellow.......	0.24	2.17
25	84	88	" "	" " " " "	White and light yellow.......	0.21	2.05
26	88	91	" "	Medium and fine sand.......	White and light yellow.......	0.24	2.00
27	91	95	" "	Coarse, medium and fine sand.	White and light yellow.......	0.27	1.85
28	95	99	" "	" " " " "	White and light yellow.......	0.29	1.62
29	99	103	" "	" " " " "	White and light yellow.......	0.26	1.67

TABLE 12 (*Concluded*)

Well 8 (*Concluded*)

Sample No.	Depth Below Surface Feet From	To	Kind of Sampling	Character of Material	Color	Mechanical Analysis Effective Size	Uniformity Coefficient
30	103	105	Sand bucket.	Coarse, medium and fine sand.	White and light yellow.......	0.225	1.84
31	105	109	" "	Coarse gravel; coarse and medium sand............	White and light yellow.......	0.33	56.10
32	109	113	" "	Gravel; medium and fine sand.	White and light yellow.......	0.28	2.11
33	113	117	" "	Coarse, medium and fine sand.	White and light yellow.......	0.27	1.91
34	117	121	" "	" " " " "	White and light yellow.......	0.19	2.00
35	121	125	" "	Medium and fine sand.......	White and light yellow.......	0.185	1.73
36	125	128	" "	" " " "	White and light yellow.......	0.14	1.96
37	128	132	" "	Fine and superfine sand......	Light brown....	*0.15	
38	132	136	" "	" " " "	" "	0.07	3.29
39	136	138	" "	" " " "	" "	0.085	2.82
40	138	142	" "	Coarse, medium and fine sand.	White and light yellow.......	0.21	2.50
41	142	146	" "	" " " " "	White and light yellow.......	0.285	2.03
42	146	150	" "	Gravel; coarse and medium sand....................	White and light yellow.......	0.315	2.03
43	150	155	" "	Coarse and fine gravel; coarse and medium sand.........	White and light yellow.......	0.32	10.00
44	155	158	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.72	36.11
45	158	162	" "	Compacted clay and sand intermixed................	Yellowish green..	....	....
46	162	166	" "	Gravel; sand; trace of clay....	" "	0.43	4.42
47	166	170	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.57	42.11
48	170	173	" "	Coarse and fine gravel; coarse sand.....................	White and light yellow.......	0.38	2.16
49	173	177	" "	Gravel; medium and fine micaceous sand................	Light gray......	0.32	7.81
50	177	181	" "	Coarse and medium micaceous sand.....................	" "	0.285	1.84
51	181	185	" "	Medium and fine sand; sandstone....................	" "	0.24	2.17
52	185	189	" "	Gravel; coarse, medium and fine sand.................	" "	0.29	1.89
53	189	193	" "	Coarse, medium and fine sand.	" "	0.25	2.20
54	193	197	" "	" " " " "	" "	0.32	1.56
55	197	202	" "	" " " " "	" "	0.37	1.46

* 60 per cent. finer than

of 400 to 500 feet; one was driven to 820 feet and another to 940 feet below the surface. There have been no indications of the clean water bearing gravels below the upper clay beds at depths of 150 to 200 feet, which form an important water horizon at some of the stations of the Ridgewood system in western Long Island.

As indicated in the probable cross-section of Long Island, Sheet 22, Acc. L 601, the blue or black clays do not form continuous layers that could be considered anything like an impervious floor. They evidently lie in lenticular masses, irregularly interstratified with the fine gray sands. Even without an impervious clay floor at any depth, it is evident that the supply of fresh water to the deep beds of gray sands must come from the surface through several hundred feet of fine sand and clay above them.

Fallacy of Connecticut Origin of Long Island Ground-Waters

The impossibility of fresh ground-waters reaching Long Island from the mainland has been discussed on page 73 of this report. The coarse gravels, if they exist in continuous beds in the lower portion of these gray sands beneath the south shore of Long Island, cannot possibly receive any water from the Connecticut shore. Sheet 22, Acc. L 601, shows that no fresh water can reach these strata through the impervious bed-rocks or the equally impervious blue clays or boulder clays which cover these bed-rocks in Connecticut, and form a more or less continuous mantle over the cretaceous beds. The gray sands and gravels found on the north side of the island do not extend as far as the Connecticut shore and are without doubt filled with salt water under the sound.

COLLECTION OF GROUND-WATER IN YELLOW GRAVELS

Considering the absence of the gray gravels at moderate depths in southern Suffolk county, and the obstacles to the movement of ground-water in the fine gray sands that are presented by the thick interstratified clay beds, the greater part of the southerly flowing ground-water that it is proposed to collect in Suffolk county must flow in the coarse yellow sands and gravels, and should be gathered in them.

Both wells and infiltration galleries have been adopted for large ground-water developments on Long Island, and these types of construction will now be considered for the proposed Suffolk County collecting works.

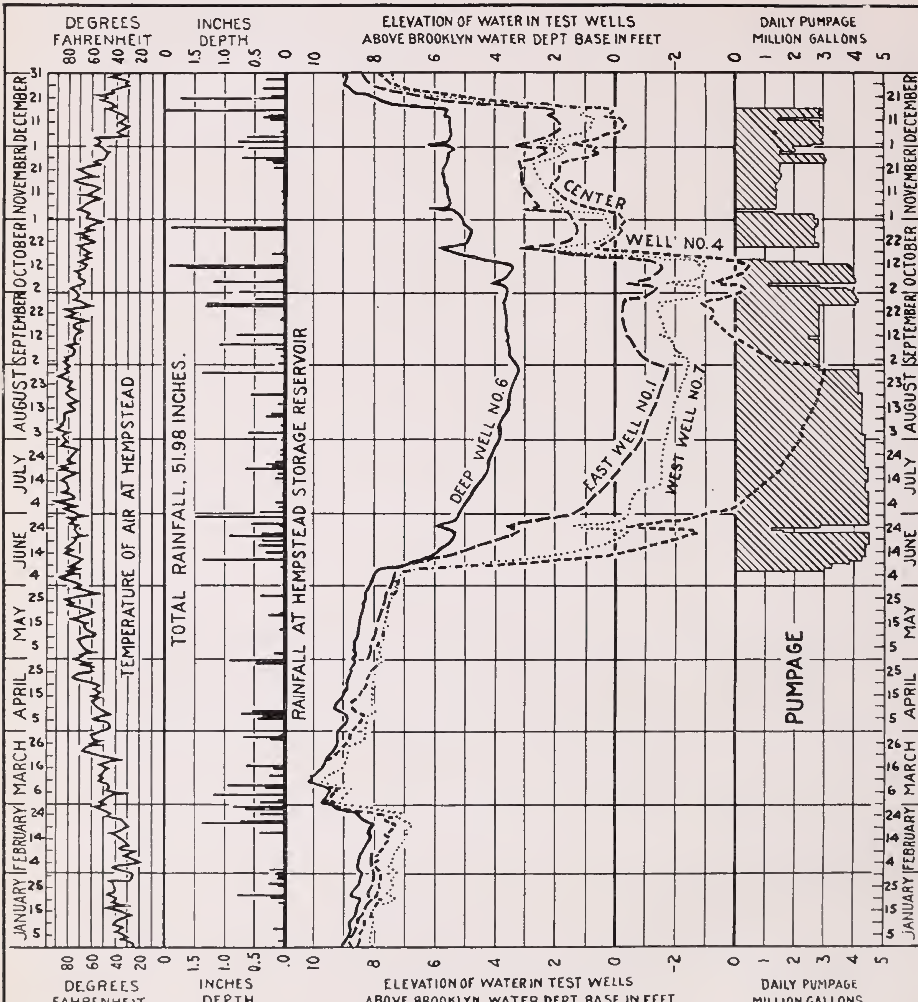
WELL SYSTEM

Except as the ground-waters reach the surface in springs, which were one of the earliest and purest sources of domestic supply, the waters in the earth have generally been obtained from wells of one form or another. On Long Island and elsewhere in similar formations, the collection of even large supplies of ground-water by other means is still exceptional. From the many types of wells that have been designed it is essential to determine that which best meets the conditions imposed by the Suffolk County conditions, and find the proper size, depth and spacing.

Depth of Wells

The geological sections of southern Suffolk county show that layers of fine and medium sand separate the coarser yellow gravels from which it is proposed to draw the supply. These strata of fine sand are not impervious and do not prevent the vertical movement of the ground-water, but the flow of much water through them transverse to their beds, results in considerable loss of head. Shallow wells in the upper strata of the yellow gravels would only intercept the entire ground-water flow by a lowering of the ground-water surface at the wells, sufficient to give a difference in head between the deep yellow gravels and the surface strata, equivalent to the friction losses through or around the semi-impervious layers.

The interference to free vertical movement of ground-waters by strata of medium and fine sand, is illustrated in diagrams, Sheets 24, 25 and 26, Accs. L 342, L 343 and L 616, which are taken from the report of the Burr-Hering-Freeman Commission. The first diagram, Sheet 24, Acc. L 342, shows the effect of pumpage at the Merrick driven-well station of the Brooklyn works. Although the water in the upper gravels where the service wells are located, was depressed 8 to 12 feet, the head in the deeper strata where there were no service wells, was lowered only three to four feet. The difference in the amount of depression represented the friction loss between the upper and lower strata, required for the movement



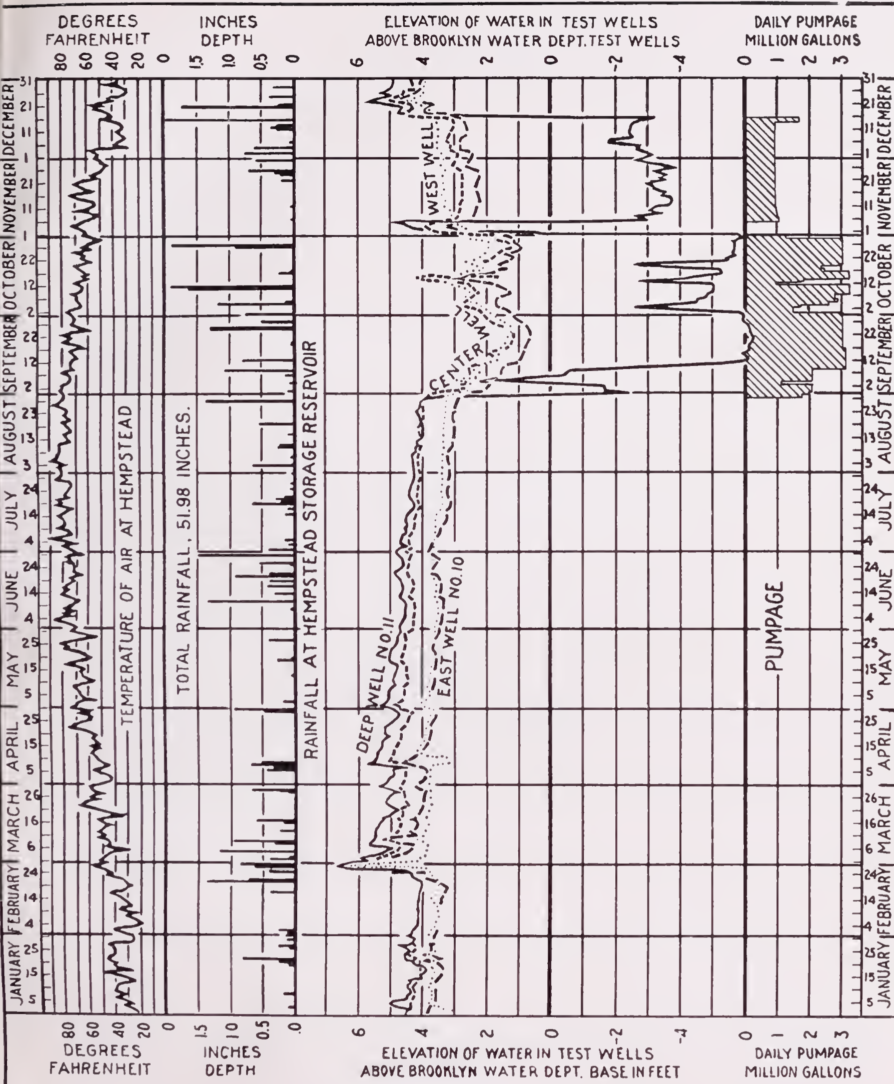
Depth of Service Wells - 45 ft.
Depth of Deep Test Well - 105 ft.
Depth of Shallow Test Wells - 45 ft.

MERRICK DRIVEN WELL STATION
OF THE
BROOKLYN WATER WORKS
EFFECT OF PUMPAGE
ON GROUND WATER
IN 1902

From Plate XII App. VII of Report of
Burr-Hering-Freeman Commission

FEB. 3 1908

B.W.S. 362 Acc. L 342



Depth of Service Wells - 33 ft to 91 ft.

AGAWAM DRIVEN WELL STATION
OF THE
BROOKLYN WATER WORKS
EFFECT OF PUMPAGE
ON GROUND WATER
IN 1902

From Plate XI App VII of Report of
Burr-Hering-Freeman-Commission

B.W.S. 364

FEB. 3 1908 Acc. L 343

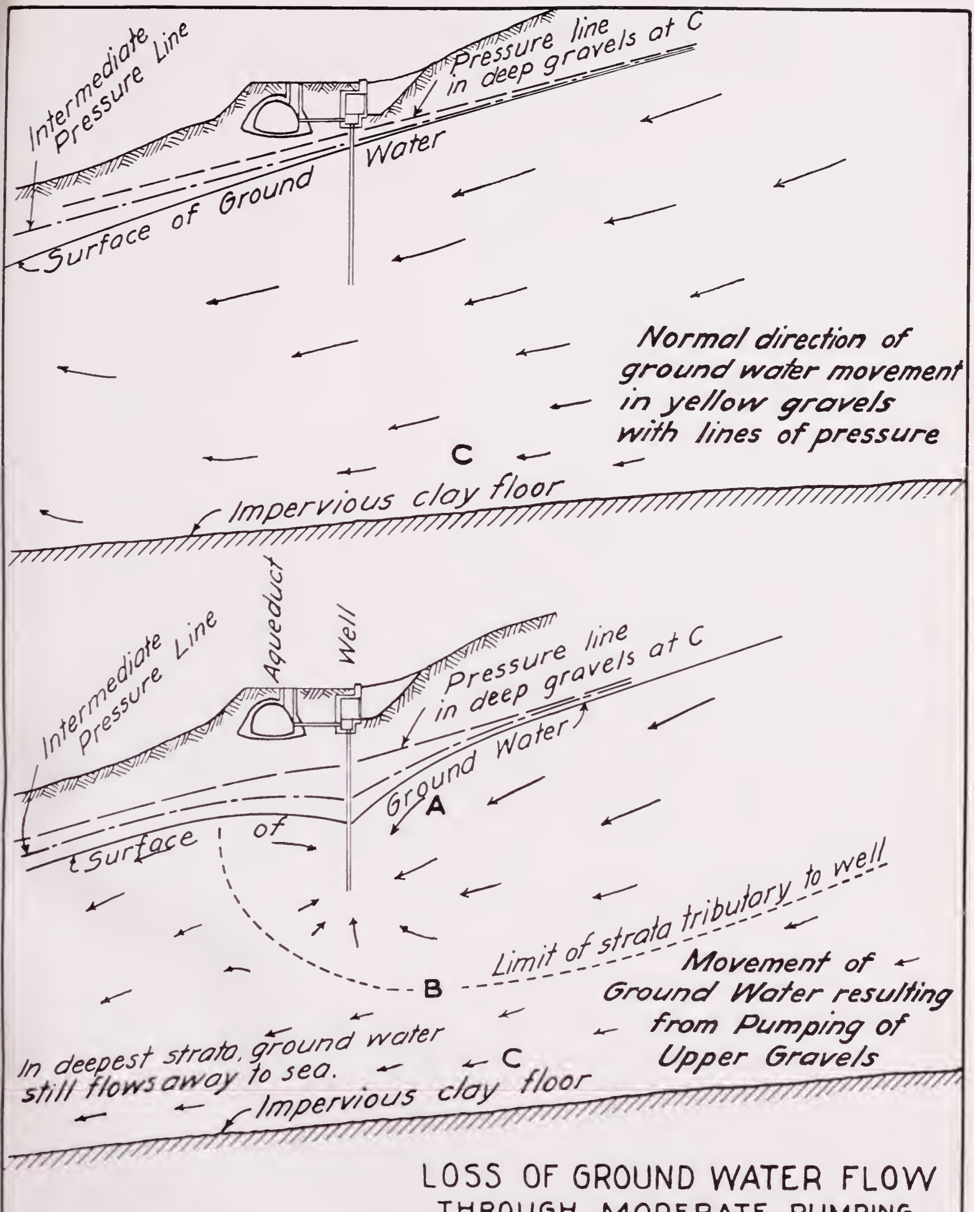
of the water upward to the wells. In like manner, the second diagram, Sheet 25, Acc. L 343, shows how little the surface-waters at the Agawam station were effected by pumping of the deeper wells.

The diagram, Sheet 26, Acc. L 616, makes still clearer the reason for the failure of a shallow well to intercept the entire ground-water movement. This diagram is intended to indicate the conditions found in southern Suffolk county, supposing the "impervious clay floor" represents the top of the fine gray sand and black clays. The normal pressure lines in the deep strata represent the artesian heads that exist along the south shore.

The pumping down of the water in the well which is represented here as penetrating only the upper gravels, most affects the pressure lines nearest the surface and may not sufficiently lower the pressure lines in the deeper strata to divert the entire flow to the well. If the well were pumped deep enough, however, the line of pressure in even the deepest strata would, of course, be lowered and inflected in both directions toward the well. Then the entire yield of the watershed would be collected. Aside from the greater lift on which the pumps would work and the resulting larger cost of operation, it has been seen that a great lowering of the water-table in southern Suffolk county is not desirable, because it may result in drawing sea-water into the collecting works, and possibly cause much annoyance to the local residents.

It is equally undesirable to drive deep wells that draw only the lower strata. If, in the example here presented, a well were driven to the clay floor and only perforated or provided with screen sections in the lower gravels, the surface slope of the ground-water in the upper gravels would not be greatly affected by a moderate lowering of the pressure in the deep strata and the flow in the upper strata would not be intercepted. In this instance, a lowering of the deep pressure gradient sufficient to intercept the surface flows would more likely draw in sea-water than if the surface ground-waters were lowered to the same depth.

If wells are driven to the full depth of the yellow gravels and screen sections or perforations are provided at all depths where the gravels are sufficiently coarse to be water bearing, the lines of pressure at the wells will be coincident at all depths, and the entire ground-water flow can be collected



LOSS OF GROUND WATER FLOW
THROUGH MODERATE PUMPING
OF SHALLOW WELLS

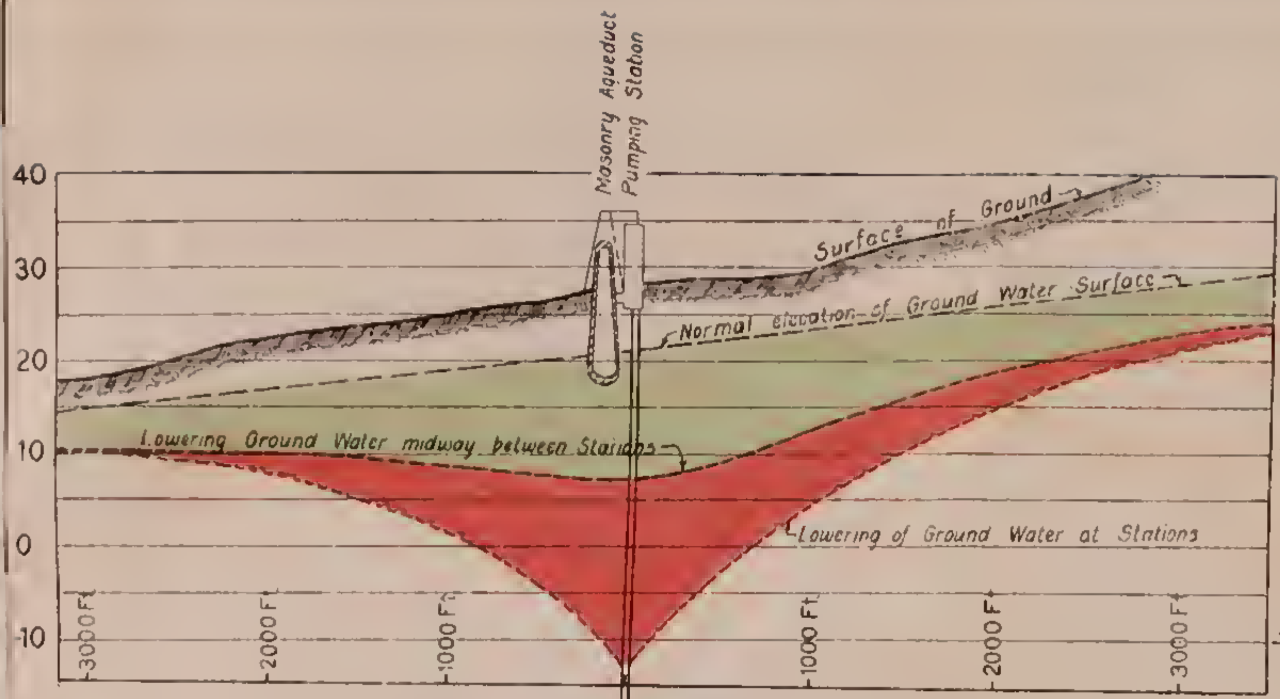
with a minimum lowering of the water-table, a minimum loss of head in the wall of the well, and a minimum lift for the pumps.

Grouping of Wells

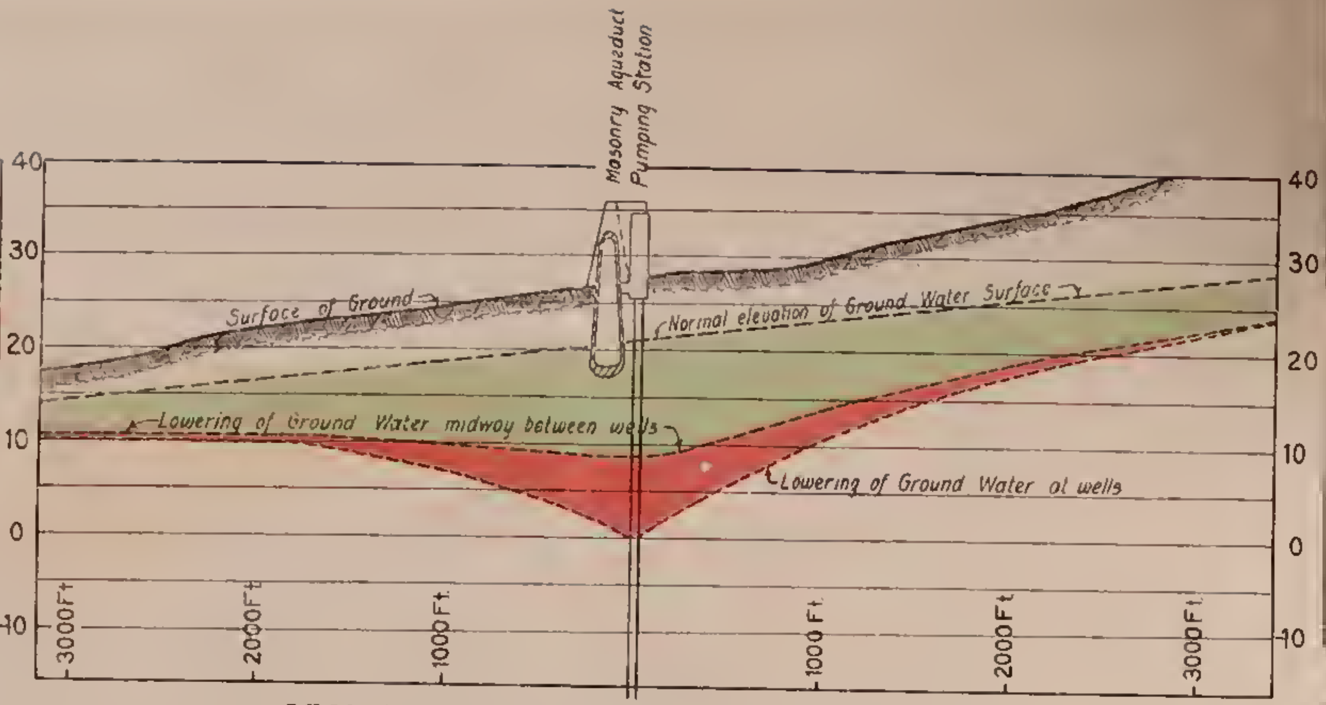
Just as it is essential to the safe and economical operation of the collecting works, to draw water directly from all strata in which it is flowing, it appears preferable, under conditions that exist in southern Long Island, to intercept the ground-water by means of a continuous line of wells at frequent intervals along the proposed aqueduct line, rather than by groups of wells at stations one to two miles apart. The depression of the water-table that is necessary to collect the entire ground-water flow and obtain adequate storage would naturally be less at each of a continuous line of wells from 500 to 1,000 feet apart, than at widely separated groups of wells.

This is brought out on Sheet 27, Acc. L 614, which shows typical transverse and longitudinal sections of the proposed collecting works in southern Suffolk county. In order that no water may escape to the sea between the groups of wells, the ground-water surface and the deep pressure gradient must, at every point on the line of the collecting works, be inflected away from the ocean towards the wells. The greater lowering of the ground-water near the groups of wells to effect this result is evident. Aside from the danger of drawing in salt water in pumping deeply at each group of wells, the greater efficiency of the pumps at the central stations is likely to be more than offset by the greater lift required by the greater depression of the water-table that is necessary at the central pumping-station.

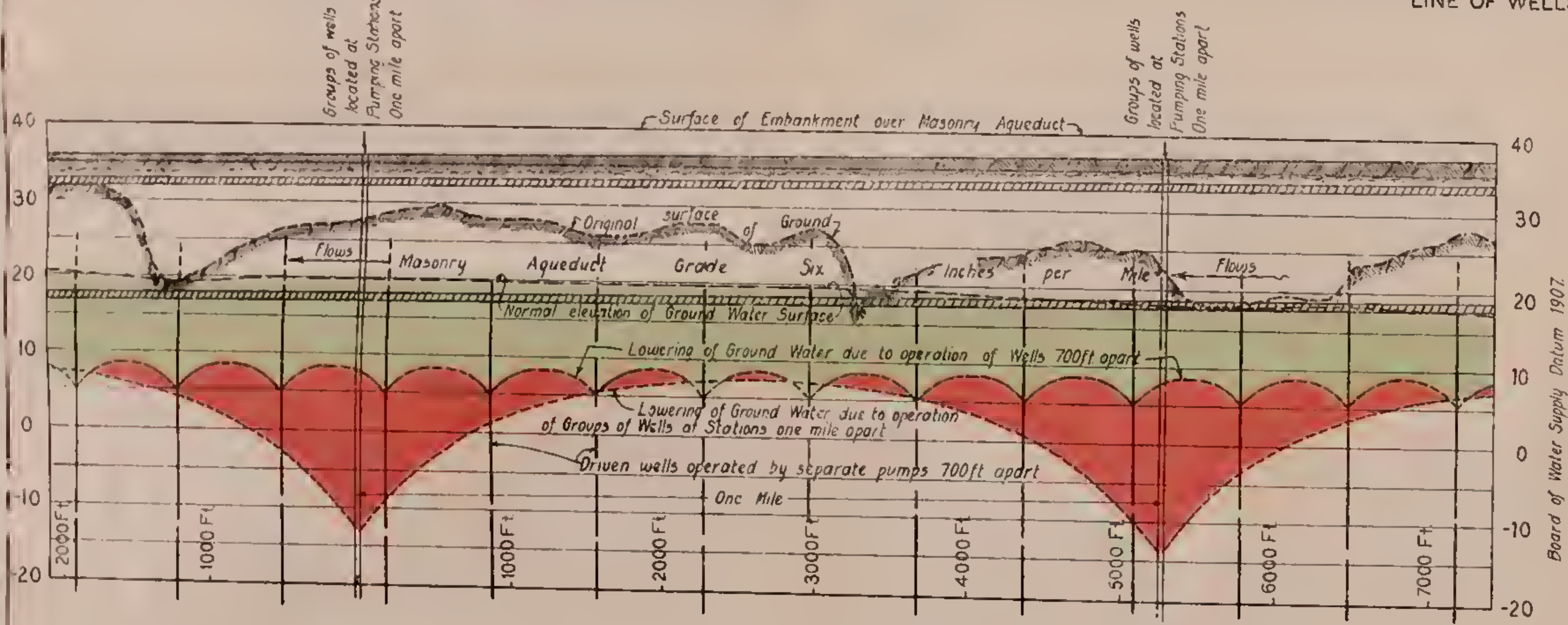
It can be stated that, with few exceptions, the water has never been lowered sufficiently at any of the old driven-well stations of the Brooklyn works to prevent the loss of some water between them. Had attempts been made to prevent the escape of water between many of the existing stations by deeper pumping, the inflow of salt water could hardly have been avoided. Furthermore, much more annoyance would have been given the local residents in Nassau and Queens counties by the greater disturbance in the surface of the ground-water near these pumping-stations.



SECTIONS AT RIGHT ANGLES TO AQUEDUCT
GROUPS OF WELLS AT STATIONS ONE MILE APART



SECTIONS AT RIGHT ANGLES TO AQUEDUCT
LINE OF WELLS 700 FEET APART



TYPICAL SECTION ALONG AQUEDUCT

City of New York
BOARD OF WATER SUPPLY

LONG ISLAND SOURCES

LOWERING OF GROUND WATER

CONTINUOUS LINE WELLS VS GROUPS OF WELLS

FEBRUARY 25, 1908

M. B. BROWN PRINTING & BINDING CO., N. Y.

Type of Wells

So important to the Long Island investigations has the selection of the proper type of wells appeared, that the well systems of all the important ground-water works both in this country and abroad have been studied with a view of securing the well most suitable for the collection of a large ground-water supply in the loose sands and gravels of Suffolk county.

European Well Practice

In Table 13 are tabulated statistics of wells that have been designed in the European ground-water works, and sketches of many of these are shown on Sheets 28 to 33, inclusive, Accs. L 76 to L 81, inclusive. The material shown here was collected by the writer in 1904, in studying many of the European water-works, and it is submitted here because it has been suggestive of many new ideas for the proposed Suffolk County works.

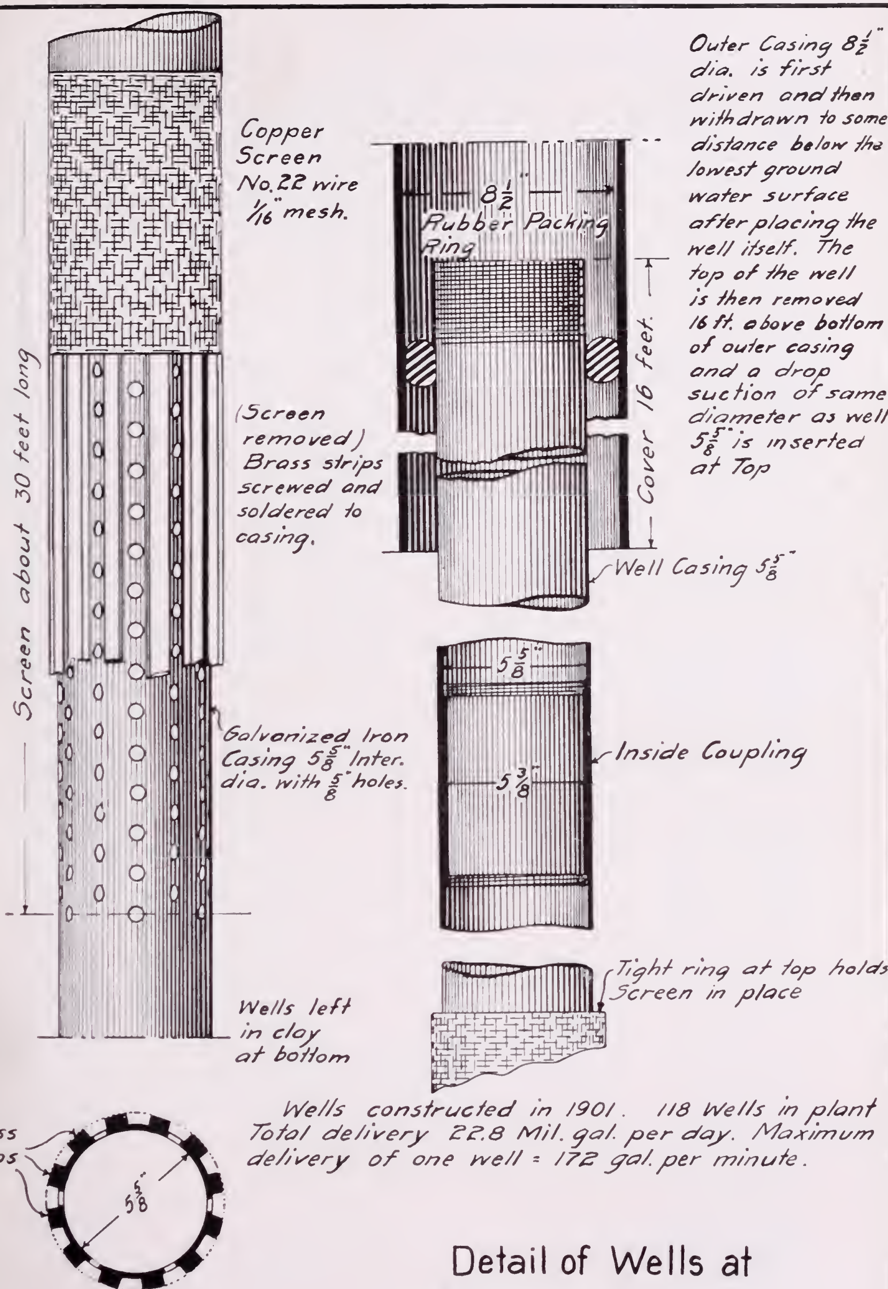
It is apparent, however, from these sketches, that they have designed nothing abroad that differs very much from the types of wells that are in use here. For shallow wells up to 40 feet in depth, there is probably nothing better than the " Dollard " or " tile " well, that was designed some years ago by a Babylon well driver to meet Long Island conditions, and which has since been used with success on the Brooklyn works. With the additional layers of graded gravels that have been placed around the Nuremberg wells (Sheets 31 and 32, Accs. L 80 and L 81), this type of well could be placed in fairly fine material.

A well after the style of those in the Wannsee plant of the Charlottenburg works, Sheet 29, Acc. L 79, in which a screen section is placed at each water bearing stratum, or the smaller well of similar construction designed by Halbertsma at Weisbaden and Tilburg (not shown) answers the requirement of permitting each water bearing stratum to be drawn upon. Sections of the ordinary wrought-iron pipe with ⅛-inch to ¼-inch holes, common in the screen section of some of the Long Island plants, would answer fully as well as the more elaborate and expensive cast-iron sections shown in the Charlottenburg wells, which, it is interesting to note, are somewhat similar to wells that were used on the Brooklyn works in the early days.

TABLE 13

TYPES OF WELLS IN EUROPEAN GROUND WATER PLANTS

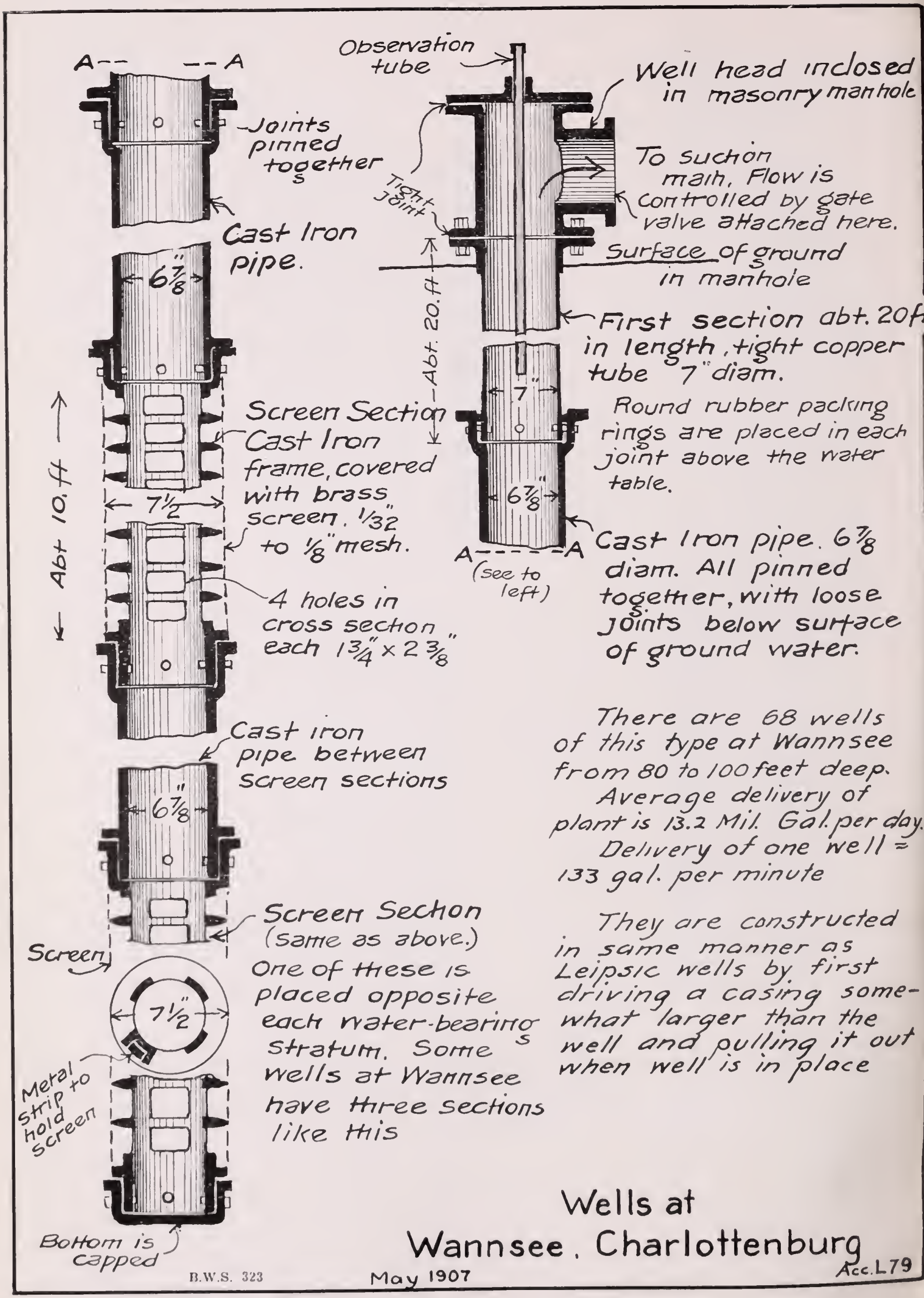
CITY	LOCATION OF SOURCE OF SUPPLY	DATE OF CONSTRUCTION OF WORK	WELLS NO. IN PLANT	WELLS SPACING IN FEET	WELLS DEPTH IN FEET	INSIDE DIAM OF WELL CASING INCHES	MATERIAL OF WHICH CASING IS MADE	LENGTH OF SCREEN SECTION IN FEET	SIZE OF PERFORATIONS IN SCREEN SECTION INCHES	APPROX. NO. OF PERFORATIONS PER FOOT	SIZE OF MESH OF BRASS SCREEN NO. OF MESHES PER IN.	OUTSIDE DIAM. OF SCREEN SECTION INCHES	DIAM. OF SUCTION IN INCHES	LENGTH OF ARTIFICAL FILTER SECTION OUTSIDE OF SCREEN SECTION FEET	OUTSIDE DIAM. OF ARTIFICAL FILTER INCHES	MATERIAL COMPOSING ARTIFICAL FILTER	YIELD TOTAL OF PLANT IN MILLION GALLONS	YIELD MAX OF EACH WELL IN GALLONS PER MIN.	NORMAL DEPTH OF GROUND WATER BELOW SURFACE FEET	APPROX. AMOUNT OF LOWERING OF GROUND WATER OF WELL FEET	PROBABLE VELOCITY OF WATER AT ENTRANCE TO SCREEN FT. PER DAY	PROBABLE VELOCITY OF WATER AT ENTRANCE TO ARTIFICAL FILTER FT. PER DAY	MATERIAL IN STRATA IN WHICH SCREEN SECTION IS PLACED	TOTAL COST OF EACH WELL WITHOUT CONNECTIONS	COST OF WELLS PER FOOT IN DEPTH	COST OF WELLS BASIS OF DELIVERY GALLONS PER MIN.
TUBULAR WELLS WITH BRASS SCREEN OVER PERFORATED PIPE																										
BERLIN	TEGELERSEE	1901	46 72	160 99	120-200 160-200	5 5/8	GALVANIZED IRON	49 34	5/8 DIAM.	90	12	6 7/8	5 5/8	NONE	—	—	11.4 11.4	172 110	7	14	377 349	—	MEDIUM FINE SAND AND GRAVEL	$ 750	$ 4.15	$ 6.82
FRANKFORT ON MAIN	HINKLESTEIN	1893	210	33	92	2 3/4	COPPER	20	1/16	976	6X25	3 1/4	2 3/4	NONE	—	—	4.9	19	45	6	215	—	MEDIUM SAND	228	2.48	12.00
TUBULAR WELLS WITH BRASS SCREEN OVER CAST IRON FRAME																										
CHARLOTTENBURG	WANNSEE	—	68	82	80-100	6 7/8	CAST IRON	10-30	1 3/8X2 3/8	24	36&8	7 1/2	6 7/8	NONE	—	—	13.2	133	—	16	890	—	FINE & MEDIUM SAND AND COARSE SAND	—	—	—
LEIPSIC	NAUNHOF	1887 1894	90 93	33 69	46	6	CAST IRON	10-16	1 5/8X2 3/8	24	4	7 3/8	4 1/2	NONE	—	—	11.9 13.2	92 98	5	23	928	—	COARSE SAND AND GRAVEL	200	4.35	2.15
UNNA	LANGSHEDE	1903	56	46	30	ABOUT 8	CAST IRON	13	1 5/8X3+	24	5	9 7/8	5	NONE	—	—	2.6	33	14	—	186	—	COMPACT MEDIUM, AND FINE SAND AND GRAVEL	240	8.00	7.27
TUBULAR WELLS WITH SLOTTED PIPE SURROUNDED BY ARTIFICAL GRAVEL FILTER																										
WIESBADEN	SCHIERSTEIN	1903	32	82	36	2 5/8	GALVANIZED IRON	11.5	1/16X1/4	1100	NONE	3	2 5/8	12	16	GRAVEL 3/16"	1.3	44	3	3	940	169	MEDIUM AND FINE SAND	—	—	—
TILBURG	TILBURG	1897	60	164	59	2 5/8	GALVANIZED IRON	26	1/16X13/16	570	NONE	3	2 5/8	27	20	COARSE SAND AND 1/16" TO 1/4" FINE GRAVEL	2.0	37	5	—	258	39	FINE SAND	—	—	—
NUREMBURG	URSPRUNG ERLENSTEGENS	1885 1896	83 32	10-65 —	12-26 33	6 7 7/8	CAST IRON ZINC COPPER	5 10	1/8X3/4 1/8X3/4	660 860	NONE NONE	6 7/8 8	6 4	8 16	32 35	FINE TO COARSE GRAVEL	2.3 3.6	30 79	— —	— —	610 750	100 125	MEDIUM SAND MEDIUM & COARSE SAND AND GRAVEL	263	7.97	3.33
HANOVER	GRASDORF	1900	19	328	30-33	6, 8, & 10	COPPER	10±	—	—	NONE	—	—	—	47	GRAVEL	2.1	77	7	4	500	130	—	408	12.75	5.30
LARGE DUG WELLS OF IRON AND MASONRY																										
DRESDEN	TOLKEWITZ	1898	10	260-300	40-50	197	CAST IRON AND BRICK	12	3/8X3 1/8	—	NONE	200	—	NONE	—	—	10.6	734	10	22	225		MEDIUM SAND AND GRAVEL	3600	80.00	4.60
AUGSBURG	HOCHABLASS	1879	5	—	30	160	CONCRETE	—	—	—	NONE	175	—	NONE	—	—	6.3	880	10	—	—	—	COARSE SAND AND GRAVEL	—	—	—

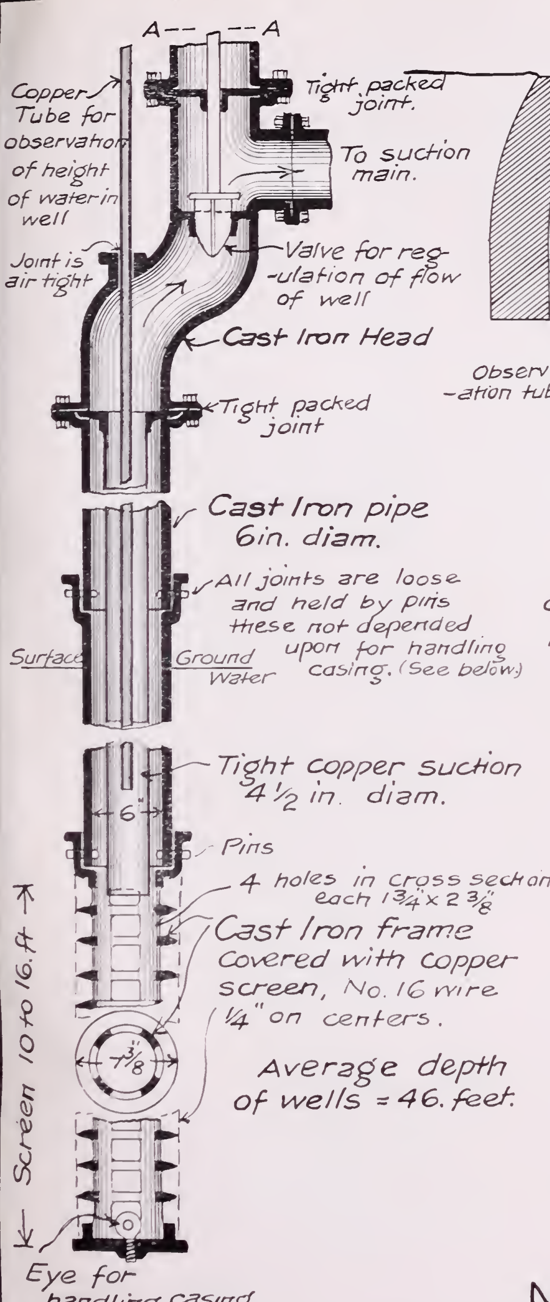


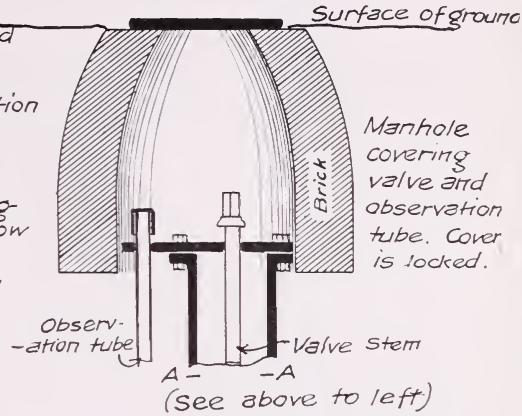
Wells constructed in 1901. 118 Wells in plant Total delivery 22.8 Mil. gal. per day. Maximum delivery of one well = 172 gal. per minute.

Detail of Wells at Tegelersee, Berlin.

B.W.S. 370 May 1907 Acc. L 77


A-- --A
Joints pinned togethers
Cast Iron pipe.
6⅞"
Abt 10 ft
Screen Section Cast Iron frame, covered with brass screen. 1/32" to 1/8" mesh.
7½"
4 holes in cross section each 1¾" x 2⅜"
Cast iron pipe between screen sections
6⅞"
Screen Section (same as above.)
One of these is placed opposite each water-bearings stratum. Some wells at Wannsee have three sections like this
Screen
7½"
Metal strip to hold screen
Bottom is capped
Observation tube
Well head inclosed in masonry manhole
To suction main. Flow is controlled by gate valve attached here.
Tight Joint
Abt. 20 ft
Surface of grounds in manhole
First section abt. 20 ft. in length, tight copper tube 7" diam.
7"
Round rubber packing rings are placed in each joint above the water table.
6⅞"
A------A (see to left)
Cast Iron pipe. 6⅞ diam. All pinned togethers, with loose joints below surface of ground water.
There are 68 wells of this type at Wannsee from 80 to 100 feet deep.
Average delivery of plant is 13.2 Mil. Gal. per day.
Delivery of one well = 133 gal. per minute
They are constructed in same manner as Leipsic wells by first driving a casing somewhat larger than the well and pulling it out when well is in place
Wells at Wannsee. Charlottenburg
B.W.S. 323
May 1907
Acc. L79





Wells of this type were constructed in 1887 and 1894 at Naunhof.

There are 183. of these wells in both plants there and together deliver an average supply of 25. Mil. Gals. per day.

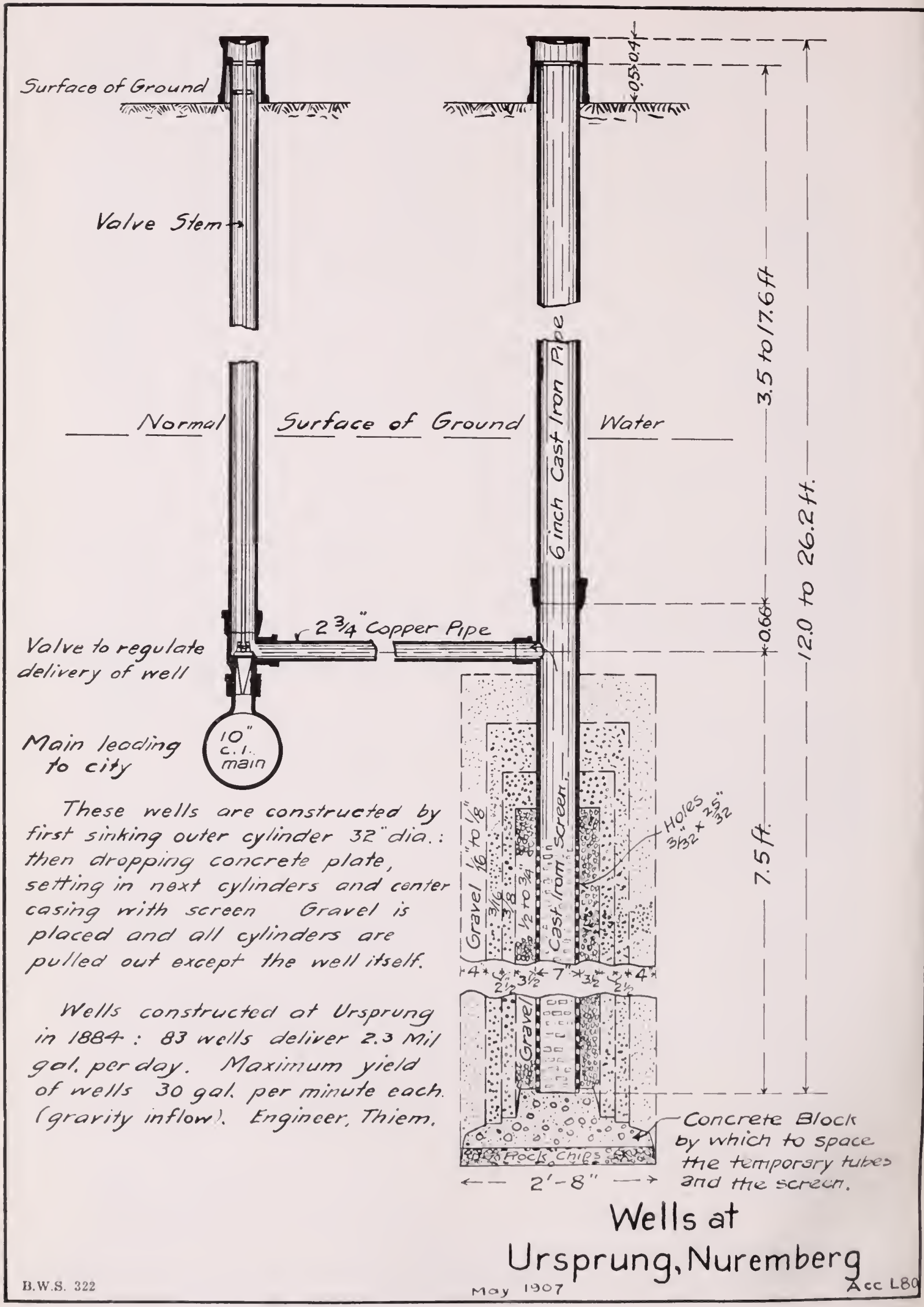
Average delivery of one well 95. gallons per minute.

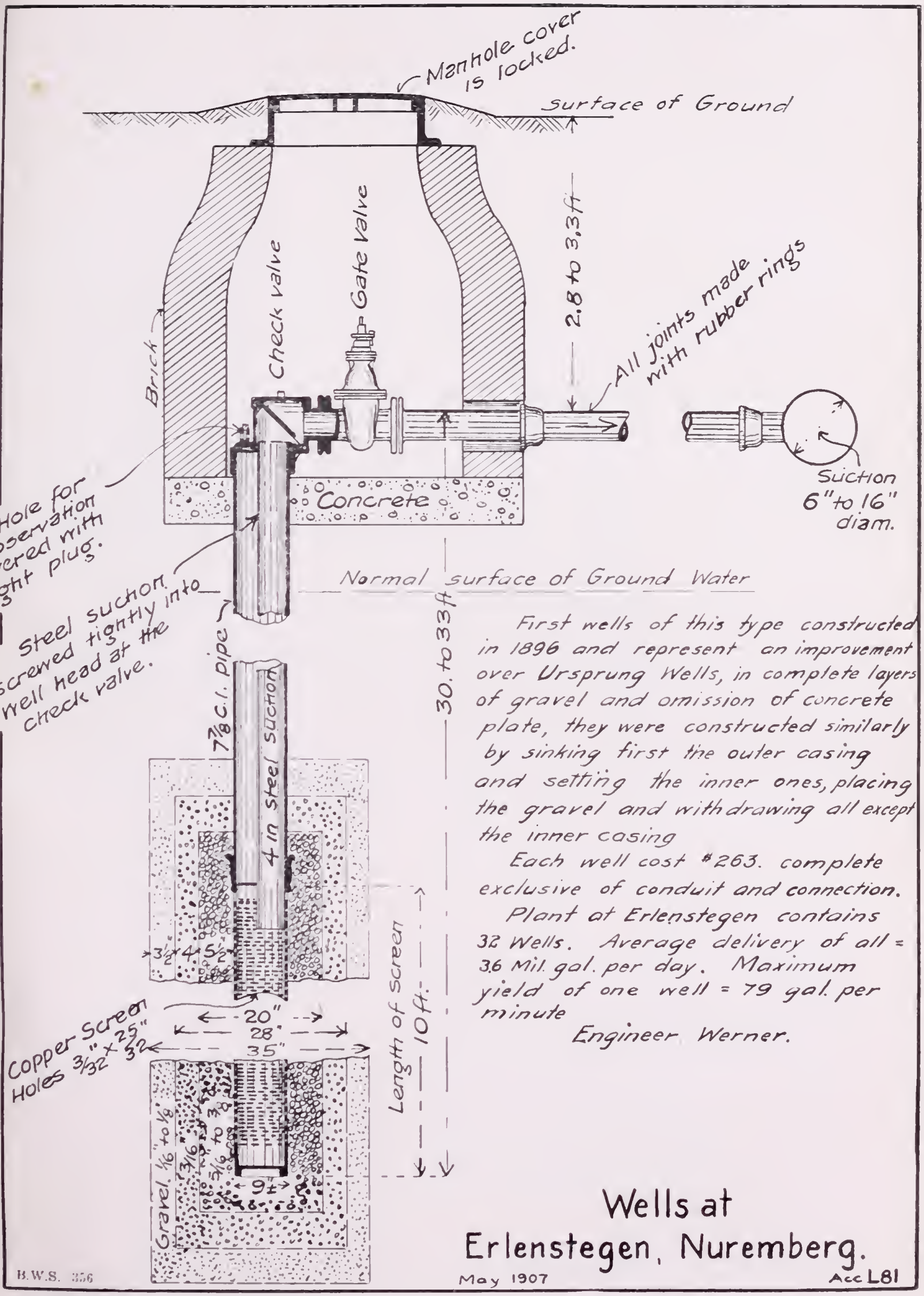
Cost of each well = $200.

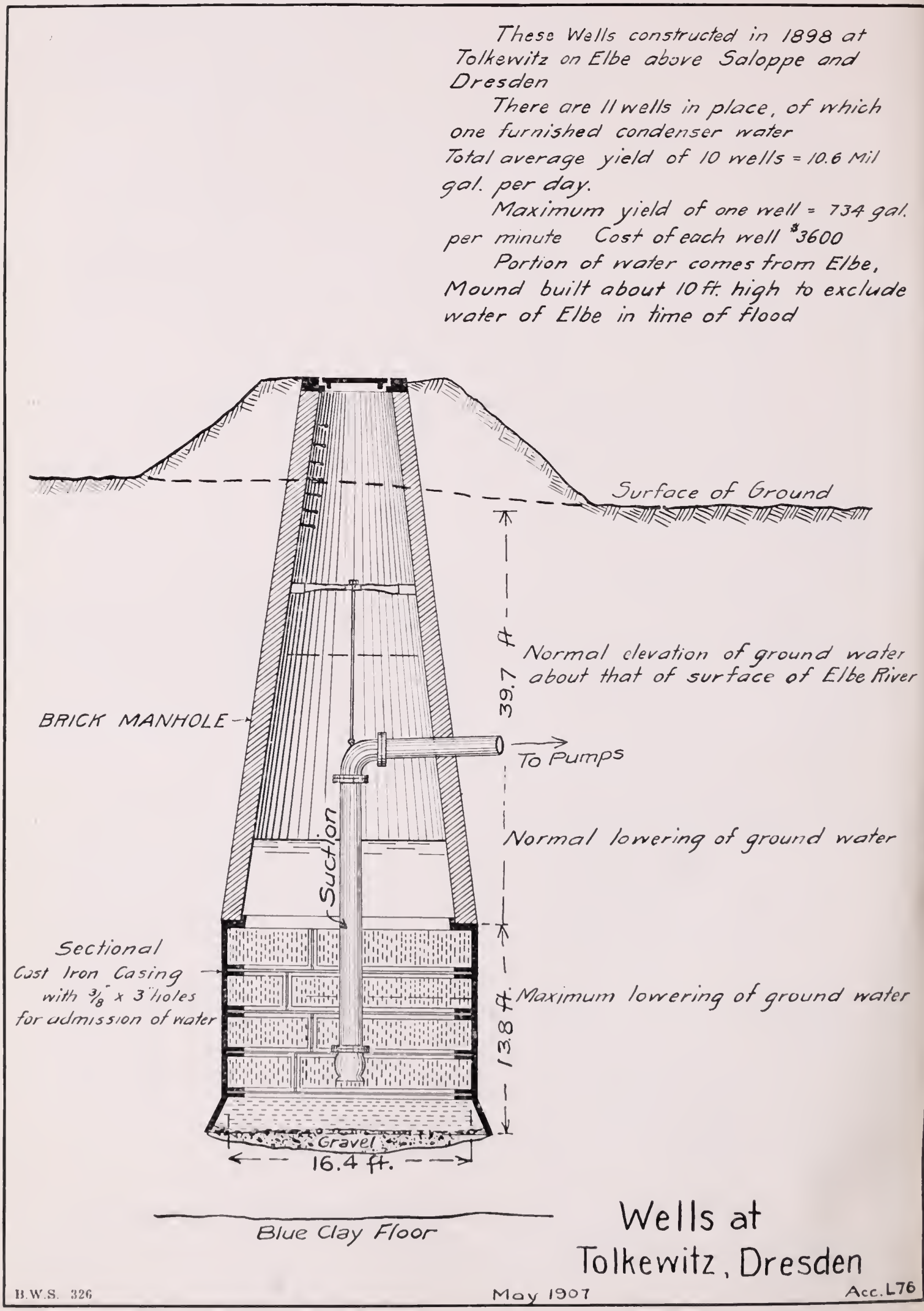
A casing somewhat larger than this well is driven first: the well is then placed within and the first withdrawn.

Wells at Naunhof, Leipsic.

B.W.S. 325 May. 1907 Acc. L78


Surface of Ground
Valve Stem
Normal Surface of Ground Water
6 inch Cast Iron Pipe
3.5 to 17.6 ft
12.0 to 26.2 ft.
0.5
0.4
0.66
2 3/4" Copper Pipe
Valve to regulate delivery of well
10" C.I. main
Main leading to city
These wells are constructed by first sinking outer cylinder 32" dia.: then dropping concrete plate, setting in next cylinders and center casing with screen Gravel is placed and all cylinders are pulled out except the well itself.
Wells constructed at Ursprung in 1884: 83 wells deliver 2.3 Mil gal. per day. Maximum yield of wells 30 gal. per minute each. (gravity inflow). Engineer, Thiem.
Gravel 1/16" to 1/8
3/16
3/8
1/2 to 3/4
Cast Iron Screen,
Holes 3/32" x 25/32"
7.5 ft.
Gravel
Rock Chips
2'-8"
Concrete Block by which to space the temporary tubes and the screen.
Wells at Ursprung, Nuremberg
B.W.S. 322
May 1907
Acc L80


Manhole cover is locked.
Surface of Ground
2.8 to 3.3 ft
Gate Valve
Check valve
Brick
All joints made with rubber rings
Concrete
Suction 6" to 16" diam.
Hole for observation covered with tight plug.
Steel suction screwed tightly into well head at the check valve.
Normal surface of Ground Water
7⅛ C.I. pipe
4 in steel suction
30. to 33 ft
Length of Screen 10 ft.
3½ 4 5½
20"
28"
35"
Copper Screen Holes 3/32" x 25/32"
Gravel 1/16" to 1/8"
9"
First wells of this type constructed in 1896 and represent an improvement over Ursprung Wells, in complete layers of gravel and omission of concrete plate, they were constructed similarly by sinking first the outer casing and setting the inner ones, placing the gravel and withdrawing all except the inner casing
Each well cost $263. complete exclusive of conduit and connection.
Plant at Erlenstegen contains 32 Wells. Average delivery of all = 3.6 Mil. gal. per day. Maximum yield of one well = 79 gal. per minute
Engineer Werner.
Wells at Erlenstegen, Nuremberg.
B.W.S. 356
May 1907
Acc L81


These Wells constructed in 1898 at Tolkewitz on Elbe above Saloppe and Dresden
There are 11 wells in place, of which one furnished condenser water
Total average yield of 10 wells = 10.6 Mil gal. per day.
Maximum yield of one well = 734 gal. per minute Cost of each well $3600
Portion of water comes from Elbe, Mound built about 10 ft. high to exclude water of Elbe in time of flood
Surface of Ground
39.7 ft.
Normal elevation of ground water about that of surface of Elbe River
BRICK MANHOLE
To Pumps
Suction
Normal lowering of ground water
Sectional Cast Iron Casing with 3/8" x 3" holes for admission of water
Maximum lowering of ground water
13.8 ft.
Gravel
16.4 ft.
Blue Clay Floor
Wells at Tolkewitz, Dresden
B.W.S. 326
May 1907
Acc. L76

American Well Practice

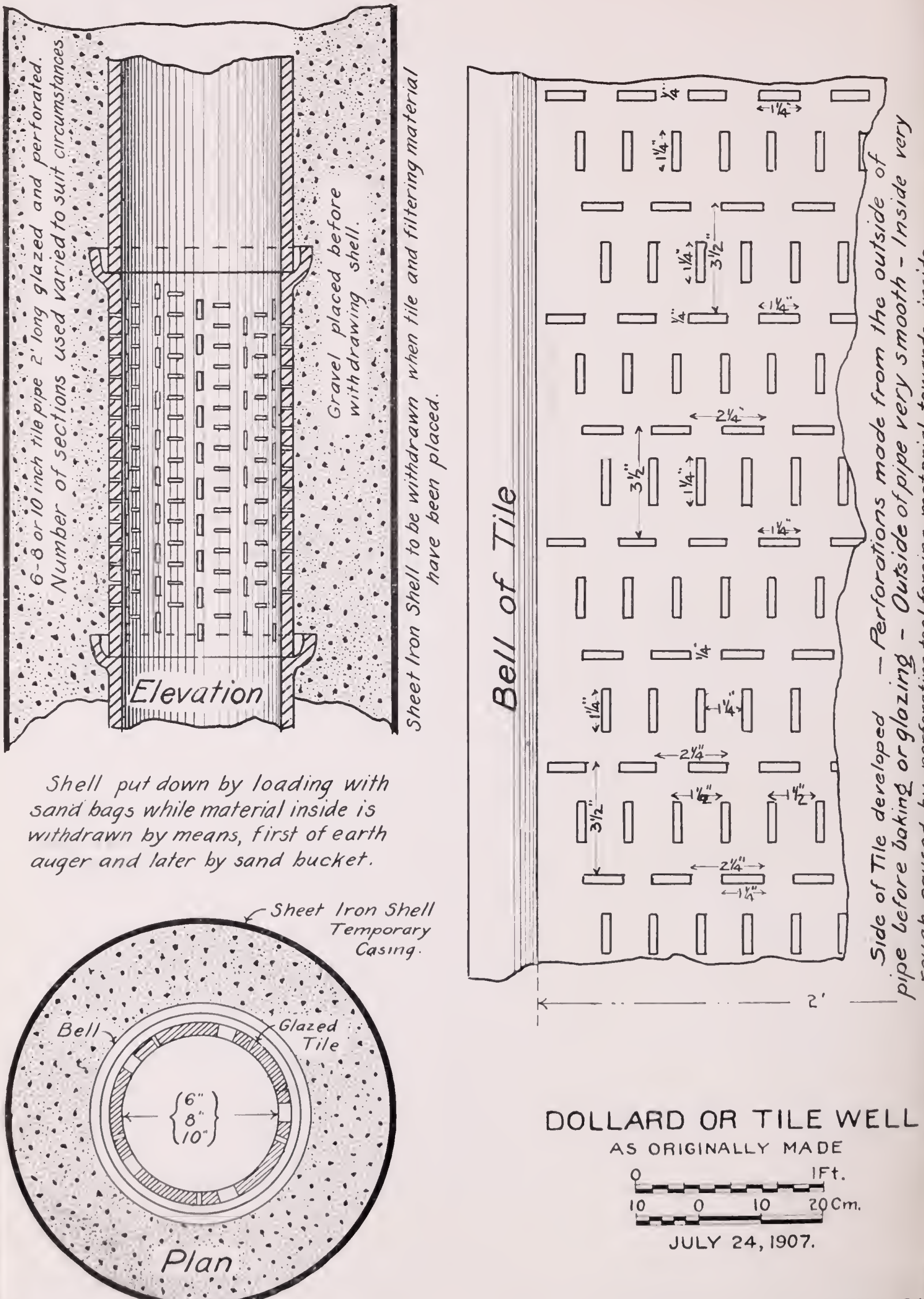
The wells of the first public water-supplies in this country were large open wells similar to the small dug wells that have been used from time immemorial for domestic supply. After them the driven well of small iron pipe came into use and these have in turn given way to larger tubular wells of iron, bronze, and vitrified clay.

The change in well practice on the Ridgewood system of the Brooklyn water-works is described by Assistant Engineer William W. Brush, in Appendix 4. The Ridgewood works represent the largest ground-water development in this country, if not in the world. Many types of wells that have been used in American practice have been tried out on the Brooklyn works and the conclusions drawn from the experience there is most important in planning works for Suffolk county. At the present time, the Department of Water Supply uses 6 to 8-inch pipe casings for deep wells and the so-called tile well 8 to 10 inches in diameter for depths of 30 to 40 feet.

In the diagrams, Sheets 34 and 35, Accs. L 204 and L 643, are exhibited a few types of wells that have not found general use on the Brooklyn works. In the first place is shown a sketch, Sheet 34, Acc. L 204, of a Dollard well and the gravel filter as originally designed, which is the prototype of the tile well of the Brooklyn works. Since the wells of the proposed Suffolk County development are to be at least 100 feet in depth, the Dollard or the tile well cannot be adopted without some modifications, because it is impossible to place the tiles and properly surround them with gravel at depths over 40 or 50 feet.

Perhaps the Germans, in the Nuremberg wells, are a little ahead of us in their more expensive perforated bronze tubes in place of the tiles, because of greater ease in handling and less danger of breakage, and for the reason that the metal tube can be pulled up and used again, while the tiles would necessarily be left in place if the well became clogged and was abandoned. Like the tile well, this bronze casing and gravel filter cannot be placed at greater depths than 40 feet.

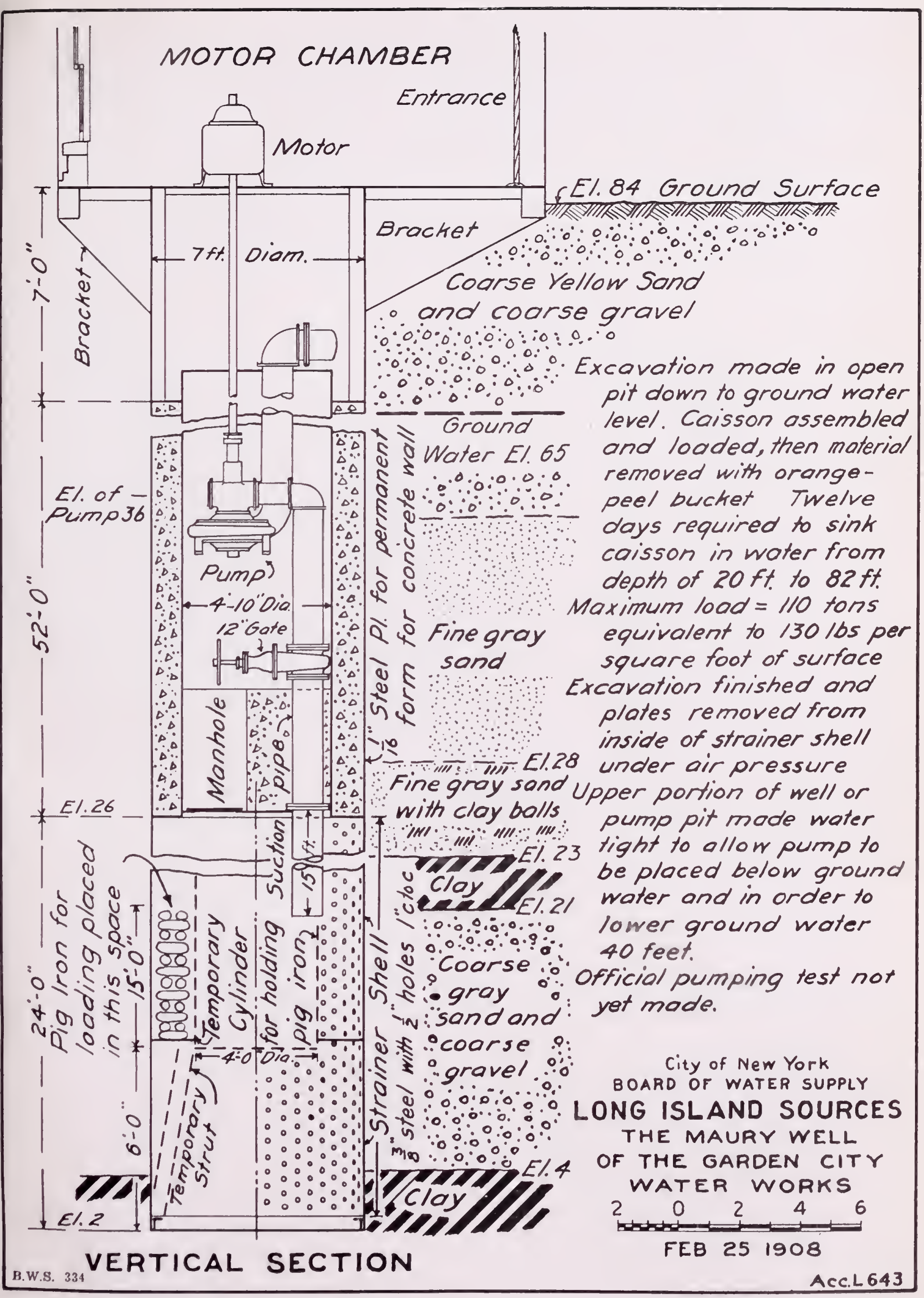
Another interesting type of well that has been designed in this country is that of Mr. Dabney H. Maury, a sketch of which is shown on Sheet 35, Acc. L 643. This represents the well driven during the past year at Garden City for the supply of that community. Wells of this type, 15 feet in diameter,



DOLLARD OR TILE WELL
AS ORIGINALLY MADE

JULY 24, 1907.

Acc. L 204


MOTOR CHAMBER
Entrance
Motor
El. 84 Ground Surface
Bracket
Bracket
7 ft. Diam.
7'-0"
Coarse Yellow Sand and coarse gravel
Excavation made in open pit down to ground water level. Caisson assembled and loaded, then material removed with orange-peel bucket Twelve days required to sink caisson in water from depth of 20 ft. to 82 ft.
Maximum load = 110 tons equivalent to 130 lbs per square foot of surface
Excavation finished and plates removed from inside of strainer shell under air pressure
Upper portion of well or pump pit made water tight to allow pump to be placed below ground water and in order to lower ground water 40 feet.
Official pumping test not yet made.
Ground Water El. 65
El. of Pump 36
Pump
4'-10" Dia.
12" Gate
52'-0"
1/16" Steel Pl. for permanent form for concrete wall
Fine gray sand
Manhole
pipe
El. 28
Fine gray sand with clay balls
El. 26
El. 23
Clay
El. 21
Suction
15 ft.
Pig Iron for loading placed in this space
24'-0"
15'-0"
Temporary Cylinder for holding pig iron
Strainer Shell 3/8" steel with 1/2" holes 1" c to c
Coarse gray sand and coarse gravel
4'-0" Dia.
Temporary Strut
6'-0"
El. 4
Clay
El. 2
VERTICAL SECTION
B.W.S. 334
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
THE MAURY WELL
OF THE GARDEN CITY
WATER WORKS
2 0 2 4 6
FEB 25 1908
Acc. L 643

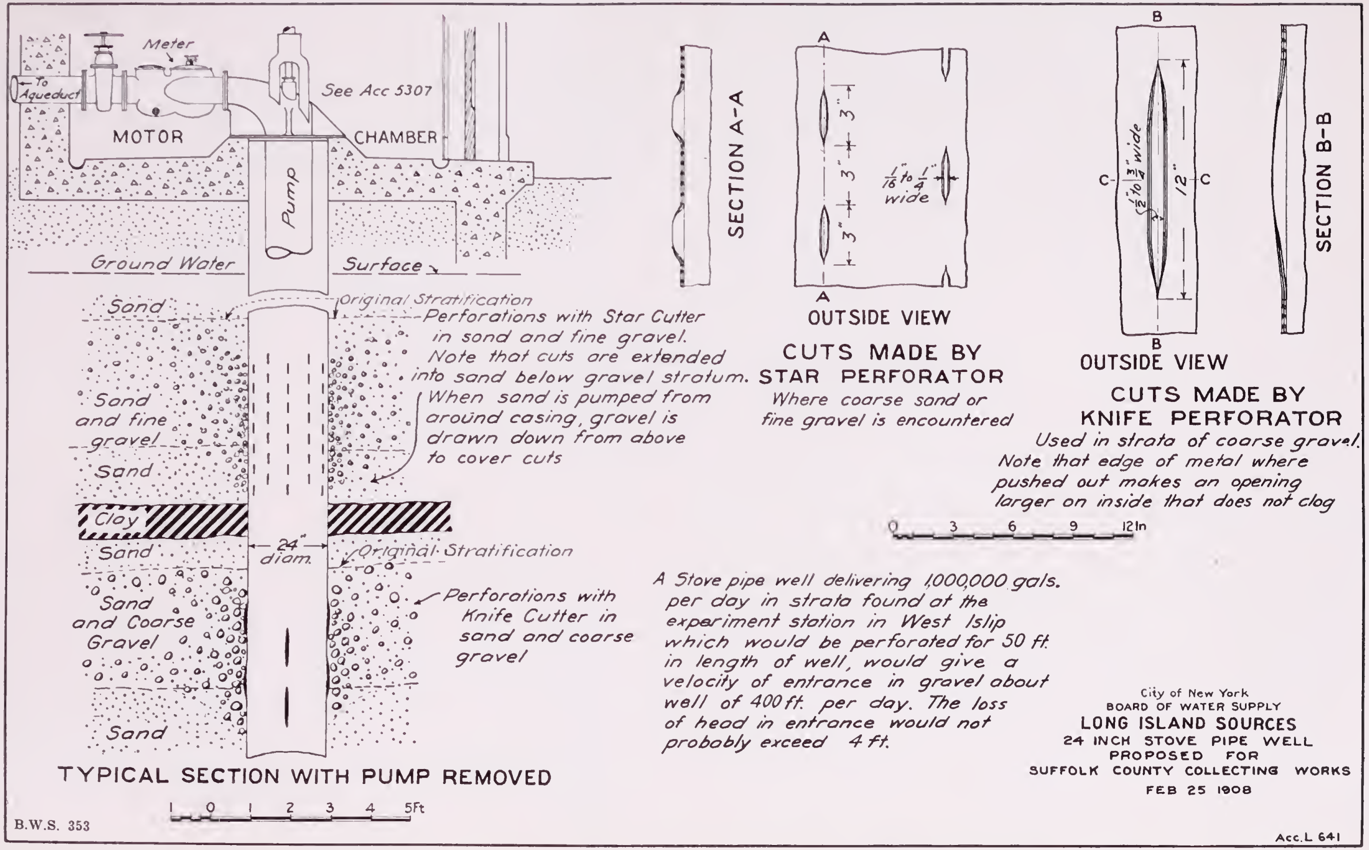
have been constructed and seem well adapted for small public supplies. For a large continuous development, such as proposed in Suffolk county, they are too expensive and cannot be driven as deeply as the water bearing gravels in Suffolk county demand. This well bears some resemblance to those of the Tolkewitz plant of the Dresden works, Sheet 33, Acc. L 76, and is in line with the tendency in favor of large wells, which is noticeable both in this country and abroad.

California Stovepipe Wells

With the amount of iron that exists on Long Island and the readiness with which it precipitates, it is quite likely in the course of time that most any well will become clogged beyond the ordinary methods of cleaning, and must be replaced. The cheapest well for any given diameter that will yield a large supply of water is, therefore, the most desirable, and the California stovepipe well promises to be the least expensive and perhaps the best well for the proposed Suffolk County works. This well, which was described in a report of the writer dated November 10, 1905, has been tried out in Suffolk county during the past year, and the results of the experiments have justified the high opinion in which this type of well is held in California.

A well of this kind, 24 inches in diameter, which is now proposed for the Suffolk County works, is shown on Sheet 36, Acc. L 641. Details of the experiments made upon the stovepipe wells near Babylon and the conclusions as to their proper size and spacing for the Suffolk County works are given in Appendix 5. It is estimated that 24-inch wells of the stovepipe type, 100 to 200 feet in depth, if driven on a large scale, may be completed for $7 per foot, which is but little greater than the cost of the much smaller wells of the Brooklyn works. This cost compares favorably with those of wells tabulated in Table 13, page 188. A stovepipe well 100 feet deep would readily yield 700 gallons per minute, which would make the cost in terms of one gallon per minute $1.

As noted on this sketch, it is essential that there be a certain amount of gravel, fine or coarse, in the sands where the perforations in the casings are made in order to form the necessary filter to exclude the finer material in the water bearing strata. Where sufficient coarse material is not found within the first 30 or 40 feet of the well, screened gravel may be



Meter
To Aqueduct
See Acc 5307
MOTOR
CHAMBER
Pump
Ground Water
Surface
Original Stratification
Sand
Perforations with Star Cutter in sand and fine gravel. Note that cuts are extended into sand below gravel stratum.
When sand is pumped from around casing, gravel is drawn down from above to cover cuts
Sand and fine gravel
Sand
Clay
24" diam.
Sand
Original Stratification
Sand and Coarse Gravel
Perforations with Knife Cutter in sand and coarse gravel
Sand
TYPICAL SECTION WITH PUMP REMOVED
1 0 1 2 3 4 5Ft
SECTION A-A
A
3"
3"
3"
1/16" to 1/4" wide
A
OUTSIDE VIEW
CUTS MADE BY STAR PERFORATOR
Where coarse sand or fine gravel is encountered
B
C
1/2" to 3/4" wide
12"
C
B
SECTION B-B
OUTSIDE VIEW
CUTS MADE BY KNIFE PERFORATOR
Used in strata of coarse gravel. Note that edge of metal where pushed out makes an opening larger on inside that does not clog
0 3 6 9 12In
A Stove pipe well delivering 1,000,000 gals. per day in strata found at the experiment station in West Islip which would be perforated for 50 ft. in length of well, would give a velocity of entrance in gravel about well of 400 ft. per day. The loss of head in entrance would not probably exceed 4 ft.
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
24 INCH STOVE PIPE WELL
PROPOSED FOR
SUFFOLK COUNTY COLLECTING WORKS
FEB 25 1908
B.W.S. 353
Acc. L 641

placed about the casing at the surface and allowed to settle down to cover the perforations as the sand is pumped out.

It is believed that the stovepipe well can be adapted to all conditions found along the line of the proposed collecting works in Suffolk county. Liberal estimates have, however, been made on the number of wells and in the unit price, in order to cover the cost of a more expensive type of well should this be found necessary in some localities where the strata may be found unfavorable for perforating the stovepipe casings.

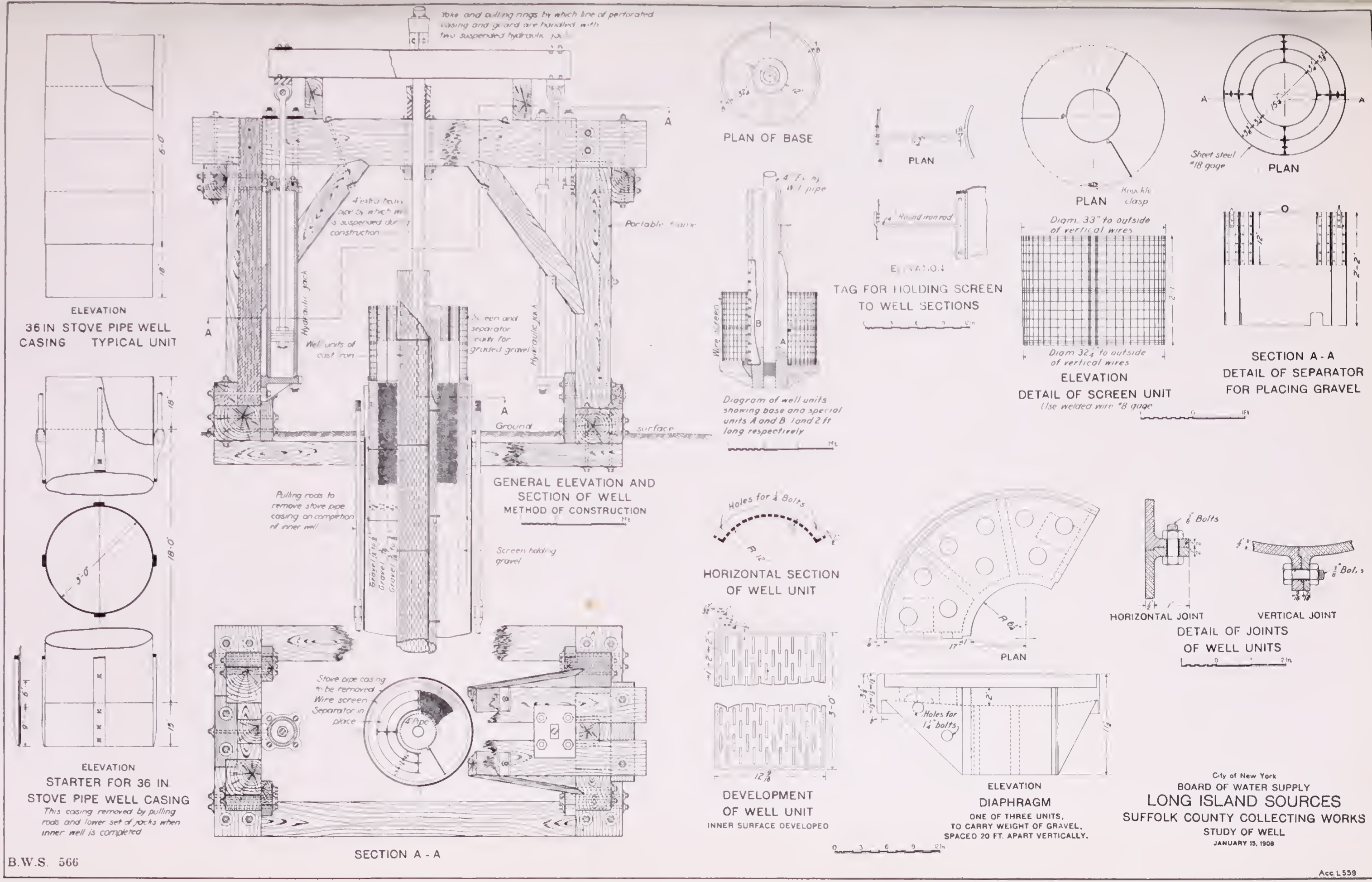
Wells with Artificial Gravel Filter

The drawing, Sheet 37, Acc. L 559, shows a study of a well with a graded gravel filter like those of the Nuremberg wells to exclude finer material than that in which the stovepipe well can be perforated. As shown in the drawing, this well is designed to be placed within a large, specially designed stovepipe casing which can afterwards be withdrawn and used again. A well of this type can be constructed to a depth of 100 feet or more. It is estimated, however, to cost about $20 per foot, which is much more expensive than the largest well of the stovepipe type, that has been considered.

Clogging of Wells

One of the most serious difficulties that has been met in the operation of ground-water collecting works on Long Island has been the clogging of the screens of the wells. This has seriously reduced the delivery of many stations in spite of efforts to keep the screens of the wells clean. The character of the sediment found in some 2-inch shallow wells of the Ridgewood system is shown below, which is taken from the annual report of the City Works Department of Brooklyn for 1896, and represents some analyses by Professor Peter T. Austin.

	Jameco—Well 24	Forest Stream—Well 14 West	Forest Stream—Well 41 East	Clear Stream—Well 42 East	Clear Stream—Well 9 West
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Silica	10	1.27	8.18	2.49	9.20
Ferric oxide	Present	78.03	74.97	15.90	68.85
Alumina	"	7.43	1.19	13.10	0.45
Magnesia	Trace	....	....	....	....
Lime	....	Present	....	Present	Present
Phosphates	Present	"	....	"	Trace
Carbonates	....	....	....	"	....
Organic matter	Present	10.33	15.71	29.18	14.15


Yoke and pulling rings by which line of perforated casing and guard are handled with two suspended hydraulic jack
ELEVATION
36 IN STOVE PIPE WELL CASING TYPICAL UNIT
Hydraulic jack
Well units of cast iron
Screen and separator units for graded gravel
Portable frame
Ground
surface
GENERAL ELEVATION AND SECTION OF WELL
METHOD OF CONSTRUCTION
Pulling rods to remove stove pipe casing on completion of inner well
Screen holding gravel
Gravel
Stove pipe casing to be removed
Wire screen
Separator in place
4" Pipe
SECTION A - A
ELEVATION
STARTER FOR 36 IN STOVE PIPE WELL CASING
This casing removed by pulling rods and lower set of jacks when inner well is completed
B.W.S. 566
PLAN OF BASE
Wire screen
Diagram of well units showing base and special units A and B 1 and 2 ft long respectively
HORIZONTAL SECTION OF WELL UNIT
Holes for ¼ Bolts
DEVELOPMENT OF WELL UNIT
INNER SURFACE DEVELOPED
PLAN
Round iron rod
ELEVATION
TAG FOR HOLDING SCREEN TO WELL SECTIONS
PLAN
Knuckle clasp
Diam. 33" to outside of vertical wires
Diam 32¼ to outside of vertical wires
ELEVATION
DETAIL OF SCREEN UNIT
Use welded wire #8 gage
Sheet steel #18 gage
PLAN
SECTION A - A
DETAIL OF SEPARATOR FOR PLACING GRAVEL
PLAN
Holes for 1¼" bolts
ELEVATION
DIAPHRAGM
ONE OF THREE UNITS, TO CARRY WEIGHT OF GRAVEL, SPACED 20 FT. APART VERTICALLY.
HORIZONTAL JOINT
VERTICAL JOINT
DETAIL OF JOINTS OF WELL UNITS
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
SUFFOLK COUNTY COLLECTING WORKS
STUDY OF WELL
JANUARY 15, 1908
Acc L559

The report accompanying these analyses stated that "The sediments * * * consist of clay, sand and ochre in various proportions. The tubes are not sufficiently corroded to make it possible that the sediments have formed to any extent by the corrosion of the iron. The cake from the outside of the tube differs from the sediment in the inside of the tubes, chiefly in the greater content of silica or sandy matter. This difference is doubtless caused by the filtration effect of the strainer, the sandy matter not being able to pass through."

After several years' use, these well points become quite filled inside with this loose reddish sediment and the fine sandy material immediately outside quite cements together, filling the small holes in the casing outside of the screen so tightly as to almost exclude the passage of water. So hard is this material that it cannot be removed by washing out the wells, and the original yield of the well can only be restored by replacing the screen section.

The suggestion of Professor Austin that this sediment, which is from 50 to 75 per cent. iron oxide, did not arise from the corrosion of the iron casing, would appear to be borne out by the recent examinations of the tile wells of the Brooklyn works. Although there is no iron whatever in these casings, yet one at the Jameco station, which was examined this spring, was quite filled with the same reddish sediment found in the small iron wells. This is an 8-inch tile well constructed in January, 1906; is 50 feet in depth, and is perforated in the lower 40 feet. The bottom of this well for 35 feet, was found to be completely filled with the reddish deposit of iron clay and fine sand, and some was found in the horizontal suction pipe leading from the well. An analysis of this sediment showed it to contain among other material:

Siliceous matter	7.6 per cent.
Oxide of iron	41.1 " "
" " aluminum	16.6 " "
" " manganese	0.7 " "

The yield of the four tile wells at this station has materially decreased during the last four years.

Another tile well at the Spring Creek station was also examined. This well was constructed at about the same time as that at the Jameco station, but only clean sand with but

a trace of iron was found. The difference in the conditions of the wells at these two stations is apparently due to the greater amount of iron at Jameco. In October, 1907, there were 7.5 parts per million in the water from the shallow wells at the Jameco station and only 0.3 part in the shallow wells at Spring creek.

The deposits in the wells are evidently made up of iron contained in solution in the ground-water which is precipitated there, and mixed with the fine sand and clay drawn in from the material surrounding the casing. Some crenothrix was found in the sediment from the Jameco well, and it is quite likely that some of the material in this well resulted from the active growth of this and other forms that thrive in waters impregnated with iron and manganese.

It is of interest to note that some of the large wells of the Tolkewitz plant of the Dresden works have contained some crenothrix, and the novel expedient of dosing these wells with potash was adopted because the crenothrix would not grow in an alkaline solution. The wells affected in this plant were those nearest the Elbe and in which the most iron occurred.

Where iron is abundant, a type of well should be chosen that has large openings to give freedom from clogging, if these iron deposits are formed. The Germans have generally used screens with a larger mesh than is common in this country, and have avoided some of the clogging experienced here. Still they have to clean their wells and a simple but effective device was adopted in the Leipsic wells for this purpose. A cylinder of wood about 8 or 10 inches long, and of slightly less diameter than the inside of the well, was attached to a long rod and churned rapidly up and down in the well. By this means the water is moved rapidly in and out through the screen and any material not a part of the filter is detached and afterwards removed.

There has not been sufficient time to study the problem of growths in wells on Long Island. It would be interesting to learn if growths of crenothrix and other organisms may occur outside of the wells in the surrounding sands and gravels, and how these growths may, if possible, be avoided.

INFILTRATION GALLERIES

An infiltration gallery is simply a large well, placed nearly horizontally in the ground below the surface of saturation,

to collect and transport the ground-water to a central pumping-station.

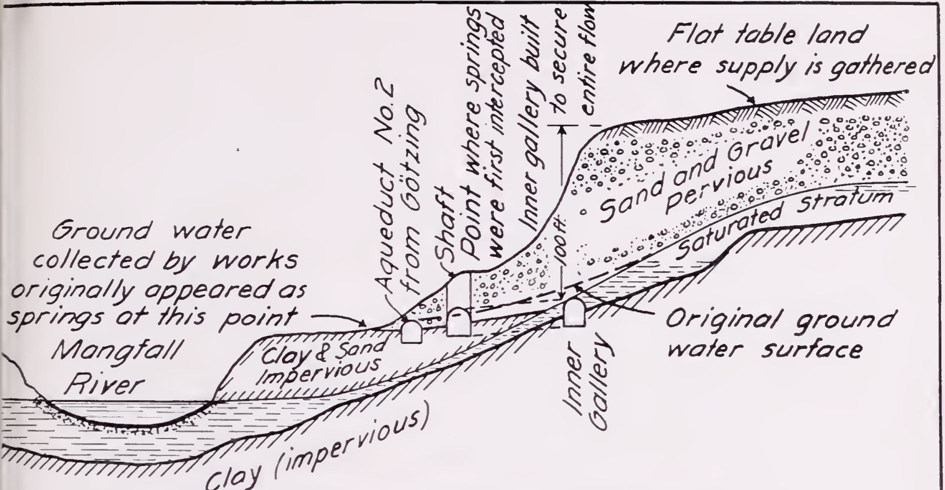
Conditions Favorable for Galleries

Under favorable circumstances, where all the ground-water from a given catchment area passes through a fairly pervious and homogeneous material above a continuous stratum of clay or rock, an infiltration gallery may be constructed on this bed of clay or rock that will intercept the entire ground-water flow. This is done successfully in the water-works of Munich, Bavaria. The general plan and a cross-section of the Muhlthal galleries, the older of the two galleries of the Munich works, is shown on Sheet 38, Acc. L 623.

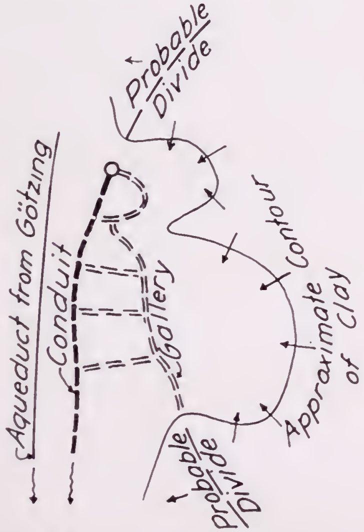
In southern Long Island, an absolutely impervious floor is only found within the limits of southern Nassau and Suffolk counties at a depth of 1000 feet or more below the surface of the ground, and the best water bearing strata, the pervious yellow gravels, have a depth of 100 to 150 feet. If an infiltration gallery was constructed at a reasonable depth, perhaps 20 feet below the ground-water surface, in the upper strata of the gravels on the line of the collecting works proposed in Suffolk county, the entire ground-water movement could not be intercepted. The reasons for this failure to gather the entire yield have already been stated for the shallow well, and they apply with even greater force to the infiltration gallery because of the greater limitations in depth at which it can be constructed.

Another serious disadvantage in an infiltration gallery is the lack of provision for ample storage during periods of drought. The water-table in the vicinity of a gallery that has been built at a moderate depth below the normal surface of saturation may be drawn down in the course of time through the operation of the works, and, as a result, the storage available for periods of drought may be greatly reduced and the yield seriously curtailed. This difficulty was experienced in the dune works at The Hague, and it was necessary there to lower the infiltration galleries at a great expense in order to secure an adequate supply. The open canals in the Amsterdam works were lowered some years ago for the same reason.

This great disadvantage in the infiltration gallery has also been demonstrated on Long Island in the Wantagh galleries



SECTION OF MUHLTHAL WORKS



PLAN OF GALLERIES

These galleries intercept the drainage from flat table land in an old valley in the clay floor now filled with pervious sands and gravels.

Total length of galleries = 4385 ft.

Average yield = 21.3 Mil. Gals. per Day

For Details of Galleries see Acc. L 64

INFILTRATION GALLERIES

MUHLTHAL WORKS OF MUNICH

FEBRUARY 25 1908

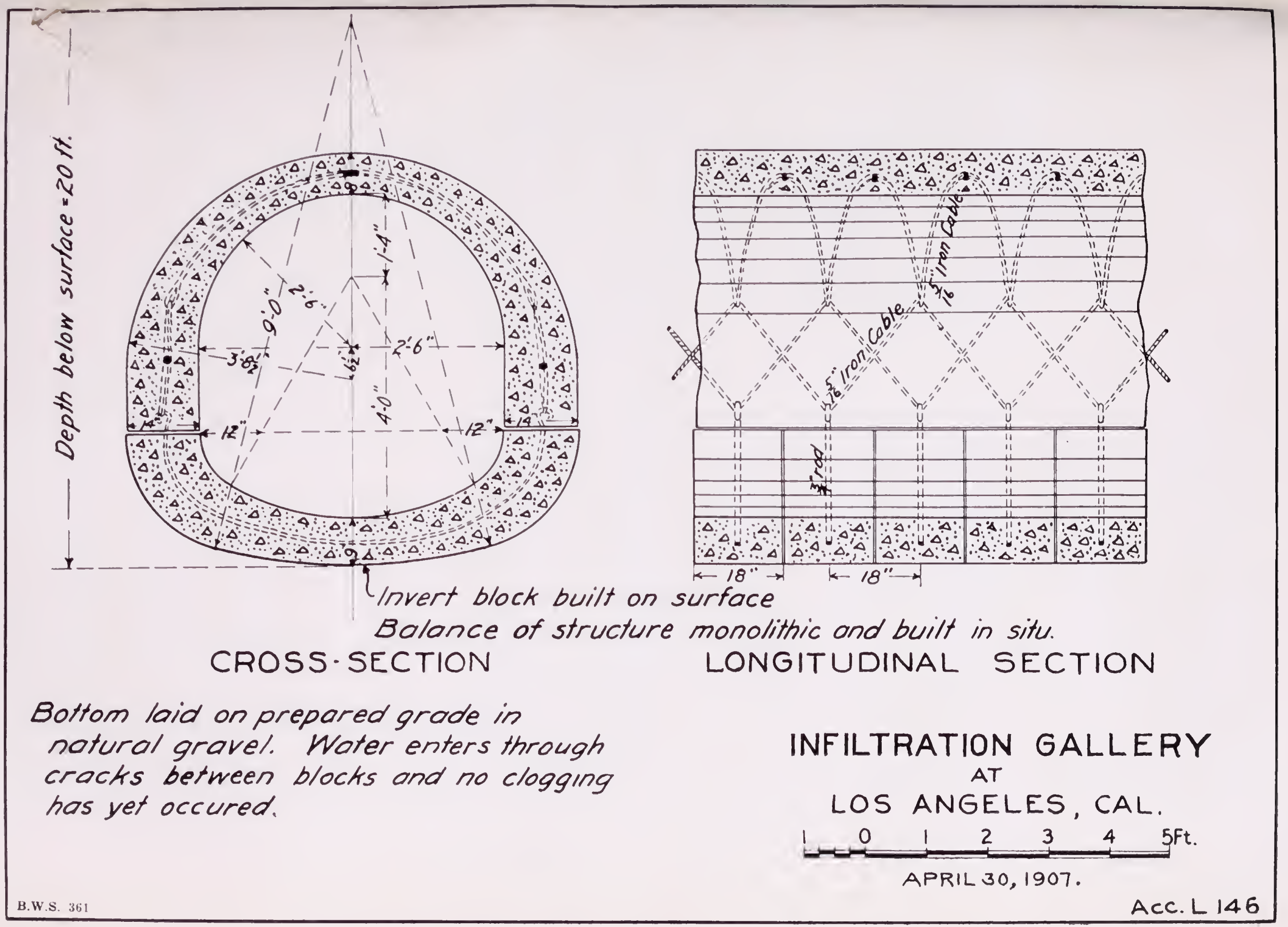
of the Brooklyn works that were constructed only three or four years ago. The ground-water near these Wantagh galleries has been drawn down to such an extent after months of operation in 1906, that the deliveries of the galleries were reduced 25 cent., as shown in Appendix 4 where this gallery is described. With continuous operation during a series of dry years, the yield of the Brooklyn galleries might readily be cut down 50 per cent. or more. Time will, perhaps, show, furthermore, that the Brooklyn galleries will encourage crenothrix growths and clog up to a large extent, because of the pumping down and exposure of the gravels about them to the air. Similar conditions in the underdrains of a filter have been most serious.

The advantages of an infiltration gallery for the conditions existing in Suffolk county should not, however, be overlooked. An infiltration gallery, if well designed, is perhaps safer from surface contamination than a system of wells. Furthermore, a gallery could be placed in southern Suffolk county at an elevation slightly above sea-level so as to exclude any possibility of drawing in brackish water from the south shore bays. On a location, however, as far from the south shore as that now proposed for the Suffolk County collecting works, there is little danger from the salt water, and this advantage of the gallery is not important.

American Practice Regarding Infiltration Galleries

Many infiltration galleries have been constructed in this country, but most of them have been built, not so much to intercept ground-water as to collect surface-waters naturally filtered through the beds of the streams beside which they are built. The most notable examples of large infiltration galleries are those near Wantagh and Massapequa, of the Brooklyn works, the construction and operation of which are fully described in Appendix 4 of this report. These galleries have yielded a large amount of water, but their construction is not of a permanent character and much time was required in building them.

A more satisfactory, though more expensive, type of gallery than those of the Brooklyn department is that constructed recently by the City of Los Angeles, which is shown on Sheet 39, Acc. L 146. This is the only gallery on the Los Angeles works, and was built because the conditions of the site were


Depth below surface = 20 ft.
2'-6"
9'-0"
1'-4"
2'-6"
3'-8½"
4'-0"
12"
12"
14"
14"
6"
$\frac{5}{16}$" Iron Cable
$\frac{5}{16}$" Iron Cable
$\frac{3}{4}$" rod
18"
18"
Invert block built on surface
Balance of structure monolithic and built in situ.
CROSS-SECTION
LONGITUDINAL SECTION
Bottom laid on prepared grade in natural gravel. Water enters through cracks between blocks and no clogging has yet occured.
INFILTRATION GALLERY
AT
LOS ANGELES, CAL.
1 0 1 2 3 4 5Ft.
APRIL 30, 1907.
B.W.S. 361
Acc. L 146

not favorable to the construction of wells, from which the remainder of the municipal supply is drawn.

The gallery is located beneath the bed of a dry run at the sources of the Los Angeles river. In the rainy season this run is filled with surface-water, to which cattle come to drink. Had wells been constructed there, they would be filled at such times with polluted surface-water from which the cover of sand protects the supply that is gathered in the infiltration gallery.

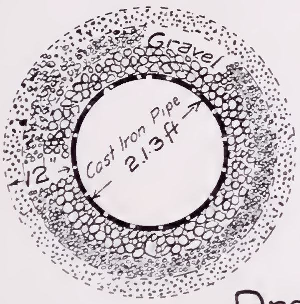
European Practice

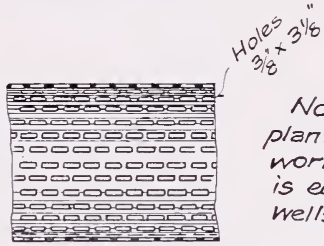
Infiltration galleries have been successfully operated in several European ground-water works, where there are great depths of sand and gravels similar to the Long Island formations. Many of these galleries are located, however, just as in the American works, near surface streams and ponds, and the water-table above them does not naturally fall much below the levels of the surface-water. Most of the water obtained in the dry seasons from these galleries is necessarily surface-water, naturally filtered by its passage through the sand composing the bed of the river. The galleries at Naples, Dresden, and Hanover are thus located.

The galleries at Brussels furnish an example of works in sand and gravel where the flow is not sustained by surface streams or ponds. These galleries were driven some years ago into a hillside near the city, at a depth below the water-table, which was originally 20 to 25 feet. The yield from these works is small, but the ground-water has been lowered over a large area since the works were built, and it seems quite probable that the present yield will in time be greatly reduced.

During the writer's study of European supplies in 1904, no new galleries were under construction. The new plants were all being equipped with wells, and in one instance, at Unna in Westphalia, the old gallery was being removed and replaced by a well system. Sketches and descriptions of several types of infiltration galleries now in service in European works are shown on Sheets 40 to 43, inclusive, Accs. L 72, L 64, L 83 and L 617. The galleries at Dresden and Hanover, Sheet 40, Acc. L 72, are comparatively old structures and have little to recommend them. Those at Munich, Brussels and Naples, Sheets 41, 42 and 43, Accs. L 64, L 83 and L 617, are of better design. Like the Los Angeles gallery, they are sufficiently large to permit of entrance and inspection, and may be readily cleaned and repaired.

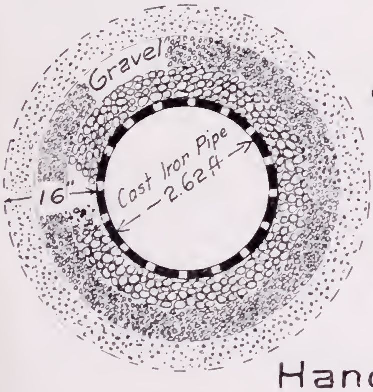
Gallery at Saloppe constructed in 1875
Length of gallery = 4700 feet.
Average rate of delivery corresponds to 5.6 Mil. Gals. per mile, mostly infiltration from the Elbe.

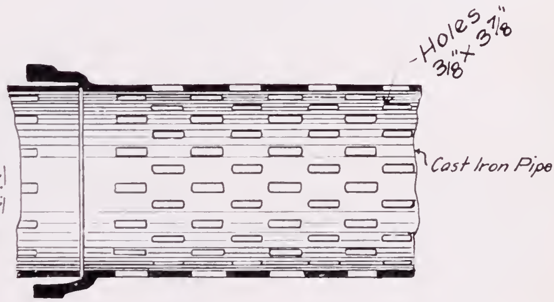




Note that new plant of the Dresden works at Tolkewitz is equipped with wells.

Dresden, Saloppe Station





Hanover, Ricklingen Station

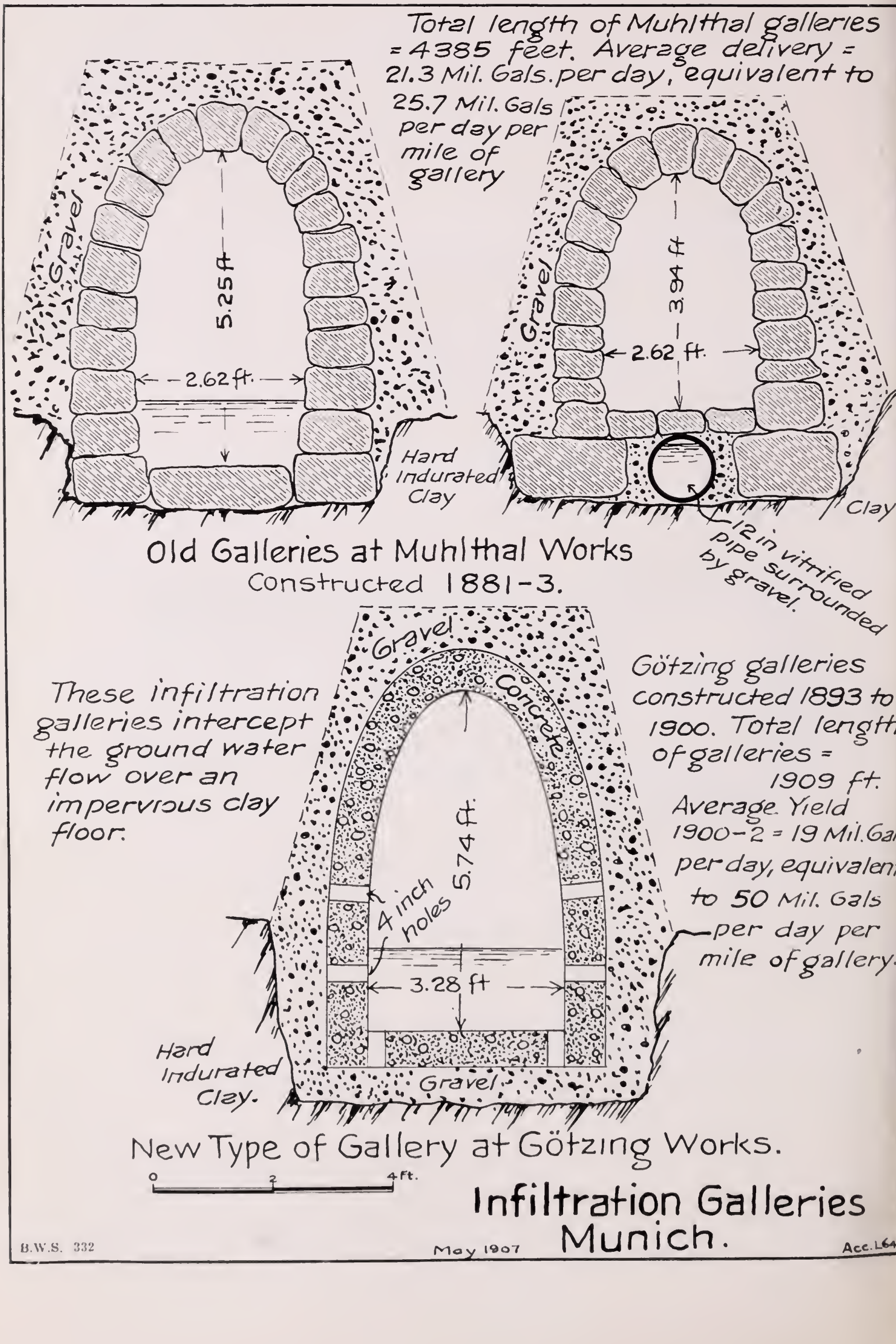
Gallery at Ricklingen constructed in 1879. Length of gallery = 3000. ft. Rate of delivery averages 4.0 Mil. Gals per mile and this volume comes from infiltration of river water.

Extension of Ricklingen works and the new station at Grasdorf were equipped with wells.

Infiltration Galleries, Dresden and Hanover.

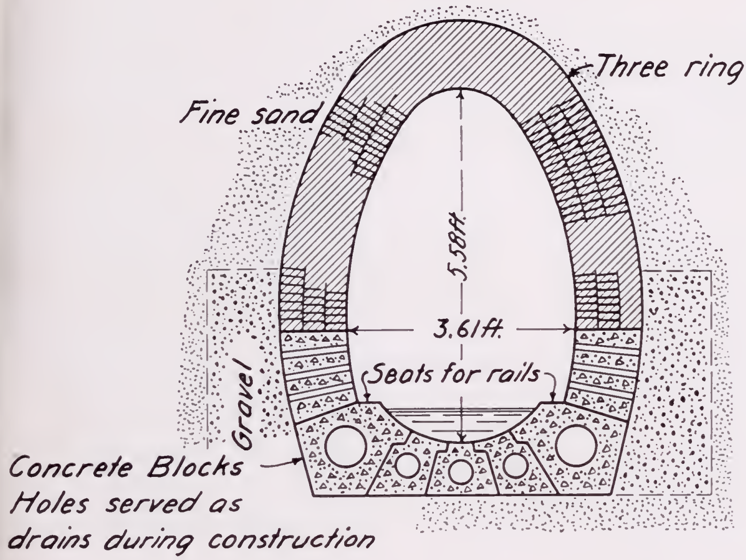
MAY 1907

B.W.S. 368 Acc L 72



Infiltration Galleries Munich.

This Gallery at Brussells completed in the Forêt de Soignes in 1873-1898
The material from which the water is drawn is a fine sand. Many difficulties were encountered and many serious accidents occured before the gallery was completed. Total length of gallery from which water is drawn = 4300 ft. Average delivery = 2.1 Mil. gal. per day.
Corresponding delivery per mile = 2.5 Mil. gal. per day.



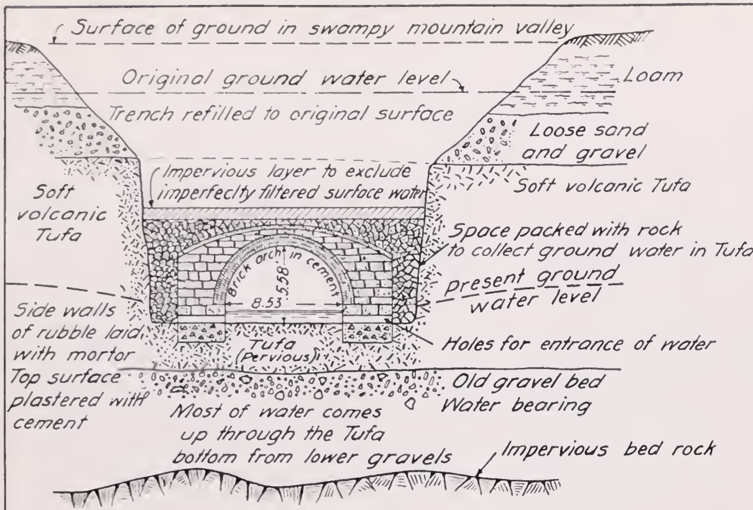
One very interesting feature of the works is the underground dam or "serrement" by which storage is increased along the line of the gallery. The general motion of the ground water is in the direction of the flow in the gallery and when the flow from a section is cut off the water must escape through the sands in a direction parallel with the aqueduct until the next perforated section is reached. The sands are fine and the slope of the water is correspondingly steep so that considerable storage is created which may be drawn upon when needed.

GALLERY AT BRUSSELLS
FORÊT DE SOIGNES

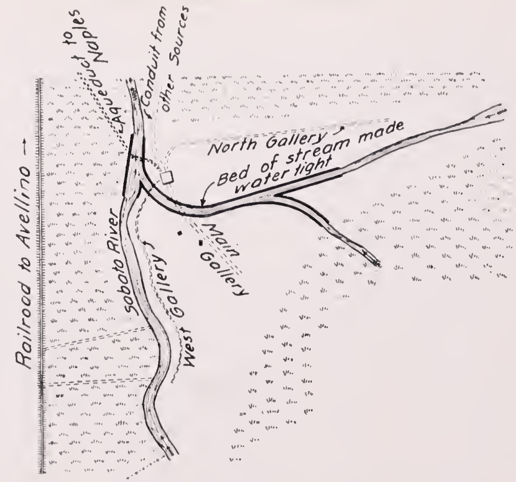
MAY 1907.

B.W.S. 331

Acc. L 83

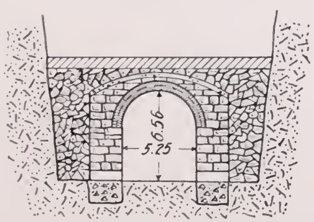


MAIN GALLERY
Length 430 Ft.



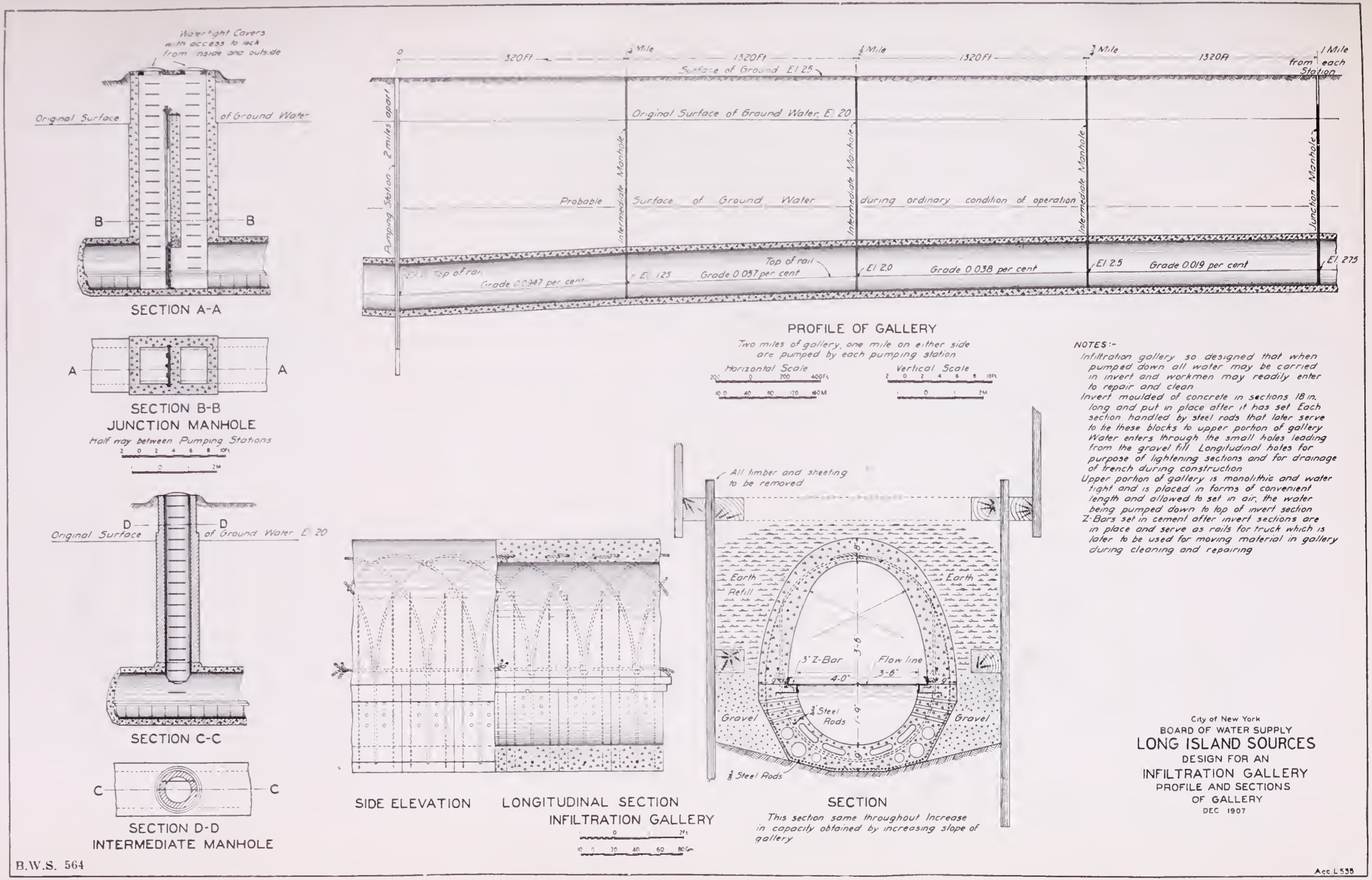
PLAN OF COLLECTING WORKS
AT URCIUOLI

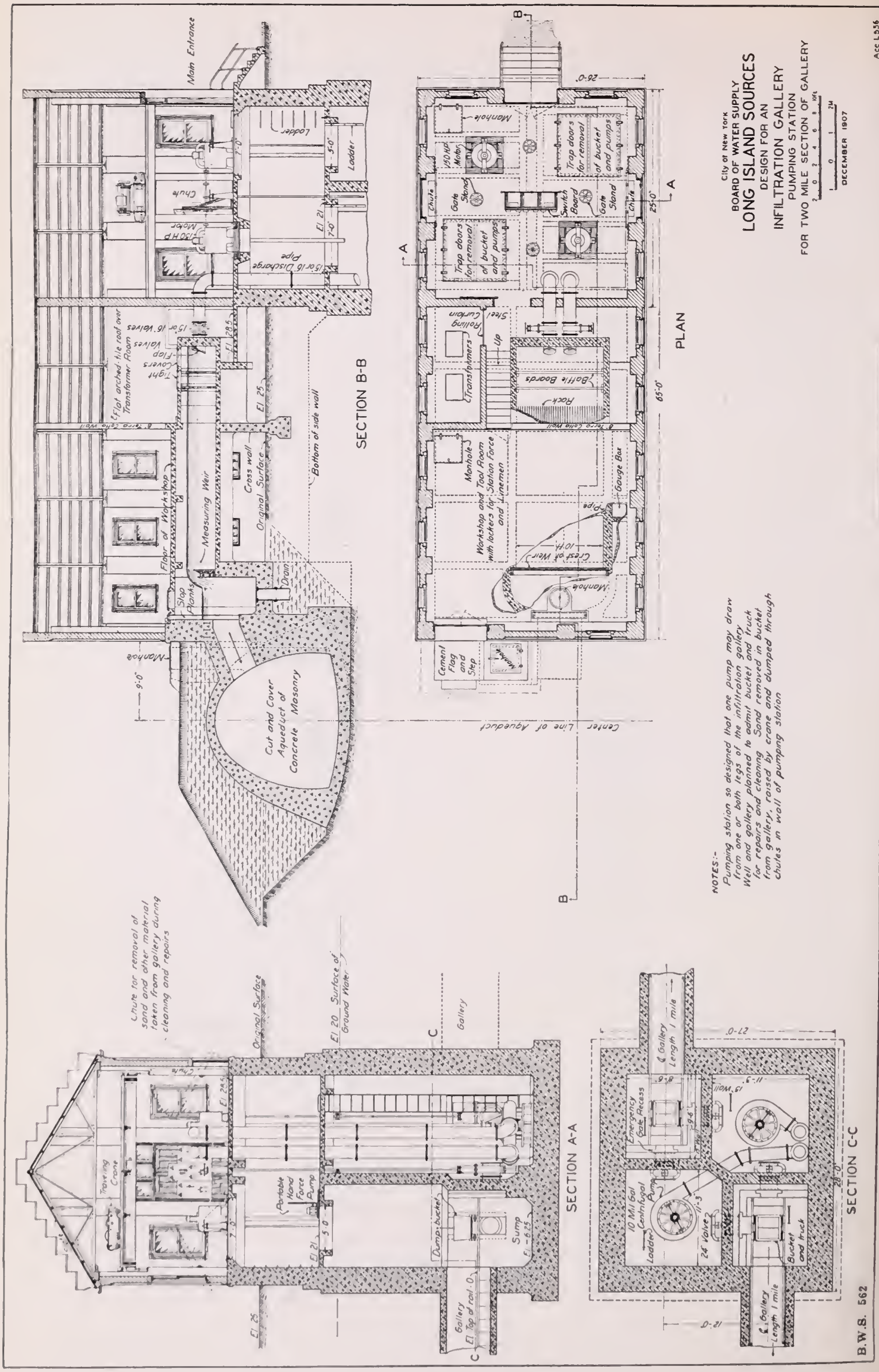
Galleries of the Urciuoli sources built near Avellino, 30 miles from Naples. in 1885
They collect ground water in the valley of Sabato River at an elevation of 1050 feet where an annual rainfall is about 55 inches including melted snow
Galleries constructed in open trench in soft Tufa and gravel in mountain valley
The beds of surface streams are made water tight to keep pollution from entering galleries
Average yield of Galleries 27.6 Mil. Gals. per Day



SECONDARY GALLERIES
North Gallery 860 feet long
West " 800 " "

INFILTRATION GALLERIES
SERINO WORKS OF NAPLES
NEAR AVELLINO
FEBRUARY 25 1908


Watertight Covers with access to lock from inside and outside
Original Surface
of Ground Water
SECTION A-A
SECTION B-B
JUNCTION MANHOLE
Half way between Pumping Stations
Original Surface
of Ground Water E 20
SECTION C-C
SECTION D-D
INTERMEDIATE MANHOLE
Pumping Station, 2 miles apart
Surface of Ground El 25
Original Surface of Ground Water E 20
Probable Surface of Ground Water during ordinary condition of operation
Intermediate Manhole
Junction Manhole
1 Mile from each Station
Top of rail
Grade 0.0947 per cent
El 12.5
Grade 0.057 per cent
El 2.0
Grade 0.038 per cent
El 2.5
Grade 0.019 per cent
El 27.5
PROFILE OF GALLERY
Two miles of gallery, one mile on either side are pumped by each pumping station
Horizontal Scale
Vertical Scale
All timber and sheeting to be removed
Earth Refill
Earth
Gravel
3" Z-Bar
Flow line
Steel Rods
SIDE ELEVATION
LONGITUDINAL SECTION
INFILTRATION GALLERY
SECTION
This section same throughout Increase in capacity obtained by increasing slope of gallery
NOTES:-
Infiltration gallery so designed that when pumped down all water may be carried in invert and workmen may readily enter to repair and clean
Invert moulded of concrete in sections 18 in. long and put in place after it has set Each section handled by steel rods that later serve to tie these blocks to upper portion of gallery Water enters through the small holes leading from the gravel fill Longitudinal holes for purpose of lightening sections and for drainage of trench during construction
Upper portion of gallery is monolithic and water tight and is placed in forms of convenient length and allowed to set in air, the water being pumped down to top of invert section
Z-Bars set in cement after invert sections are in place and serve as rails for truck which is later to be used for moving material in gallery during cleaning and repairing
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
DESIGN FOR AN
INFILTRATION GALLERY
PROFILE AND SECTIONS
OF GALLERY
DEC 1907
B.W.S. 564
Acc L 535


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
DESIGN FOR AN
INFILTRATION GALLERY
PUMPING STATION
FOR TWO MILE SECTION OF GALLERY
DECEMBER 1907
SECTION B-B
PLAN
SECTION A-A
SECTION C-C
Main Entrance
Ladder
Chute
150 H.P. Motor
15 or 16 Discharge Pipe
15 or 16 Valves
Flap Valves
Tight Covers
Flat arched tile roof over Transformer Room
Floor of Workshop
Measuring Weir
Cross wall
Original Surface
Bottom of side wall
Stop Planks
Drain
Manhole
Cut and Cover Aqueduct of Concrete Masonry
Center Line of Aqueduct
Trap doors for removal of bucket and pumps
Gate Stand
Switch Board
Steel Rolling Curtain
Transformers
Baffle Boards
Rock
Workshop and Tool Room with lockers for Station Force and Linemen
Gauge Box
Pipe
Crest of Weir
Cement Flag and Step
NOTES:-
Pumping station so designed that one pump may draw from one or both legs of the infiltration gallery.
Well and gallery planned to admit bucket and truck for repairs and cleaning. Sand removed in bucket from gallery, raised by crane and dumped through chutes in wall of pumping station.
Chute for removal of sand and other material taken from gallery during cleaning and repairs
Traveling Crane
Portable Hand Force Pump
Dump bucket
Sump
Gallery
El. 20 Surface of Ground Water
Emergency Gate Recess
10 Mil. Gal. Centrifugal Pump
24 Valve
Bucket and truck
Gallery Length 1 mile
B.W.S. 562
Acc L 556

Study of Gallery for Long Island Conditions

The drawings, Sheets 44 and 45, Accs. L 535 and L 536, represent a study for an infiltration gallery that would best meet the conditions in southern Suffolk county. Like the more recent European galleries, this design would permit of entrance for inspection, cleaning or repairs, and, like the Los Angeles gallery, it could be built in open trench. The central pumping-stations would be spaced two miles apart along the line of the collecting works. These stations would naturally be constructed first, and the gallery then built in each direction from the station. The invert blocks would be molded at the surface and placed when well set. With the drainage holes in these blocks, the section of the invert is sufficient to carry all the seepage to the trench at a level slightly below their upper surfaces. This would permit the upper portion of the concrete section to be placed dry. The reinforcement would make a monolithic structure of sufficient strength to resist rupture from irregular settlement.

Doubtless the cost of the pumping-stations could be reduced, and it might be possible to space them farther apart. But this design answers for a preliminary estimate of cost with which to compare the relative advantages of infiltration galleries and wells.

RELATIVE COST AND ECONOMY OF OPERATION OF WELLS AND INFILTRATION GALLERIES

The first cost of any type of infiltration gallery is more than a system of wells, although the greater cost of operating the wells offsets the saving in fixed charges, if works are operated continuously.

Costs of Infiltration Galleries

The total cost of the concrete filtration, of which a study has been made on Sheets 44 and 45, Accs. L 535 and L 536, to meet the Long Island conditions, is estimated as follows:

Infiltration gallery, two miles in length (not including land or water damages)	$364,000
Central pumping-stations	39,000
Total	$403,000
The cost per foot on this basis is	$38.17

This is much greater than the cost of the smaller and less expensive type of gallery constructed on the Brooklyn works at Wantagh and Massapequa, the contract prices of which were as follows:

Infiltration Gallery	Length of Gallery in Feet	Total of Low Bid on Basis of Engineer	Corresponding Price per Foot of Gallery	Estimated Safe Yield Million Gallons Daily
Wantagh........	12,300	$130,285	$10.60	10
Massapequa.....	18,200	327,850	18.00	15

The contractors on both of these galleries maintain that they have lost money, $100,000 being claimed on the contract for the Wantagh gallery. Perhaps the bids upon another gallery of this type would be still higher than on the Massapequa gallery, the last one constructed. It should be noted that neither contract provided for a permanent pumping-station, and these prices do not include land or water damages. To make the bid prices on the Massapequa gallery comparable with the estimate of cost on the design suggested in this report, at least $20,000 should be added for a permanent pumping-station, which would make the price $347,850 or $19.10 per foot.

Cost of Stovepipe Wells

Estimates have been made in Appendix 5 on a system of stovepipe wells, 24 inches in diameter, for the proposed Suffolk County collecting works. Assuming an average spacing of 700 feet there would be 15 wells in a section, equal in length to that of the gallery, two miles. With a unit price of $4,440 for each well unit, which includes well, pump, motor, concrete chamber, all electrical and water connections, and 20 per cent. for emergency and contingency, the cost of 15 well units is $16,000 without land or water damages. The average cost of this well system per foot of the line would be $6.31 or about one-third the cost of the Massapequa gallery, complete with a permanent pumping-station.

Economy in First Cost of Constructing a Well System

The first cost of a system of wells can be much reduced by first constructing the wells at greater intervals along the aqueduct than called for in complete works, or farther apart than the pumping of the first wells might show to be necessary for the collection of the whole supply, whereas a gallery is neces-

sarily completed in the first installation, even though subsequent operation might show that portions of the line gave little water.

Cost of Operation of Wells and Galleries

The estimated annual fixed charges, operation and maintenance of (1) a section of infiltration gallery in Suffolk county two miles in length of the same design as the Massapequa gallery, (2) of an equal length of the large concrete gallery suggested in this report, and (3) a 2-mile section of the system of the large stovepipe wells are shown in Table 14. From these annual charges the cost of each million gallons has been computed, assuming that an average volume of water of five million gallons per day would be collected from each mile of the works, or a total of 10 million gallons per day.

The infiltration gallery patterned after that constructed at Massapequa would provide a supply almost as cheap as that from the well system here proposed, if the works were run continuously, because of the greater cost of operating the wells. If, however, these works were run only a portion of the year, as is customary in operating ground-water works, to allow the underground reservoirs to be replenished, the well system, with its smaller fixed charges, would furnish a cheaper supply than a gallery of even the Brooklyn type. If a more permanent type of gallery were built, the cost of a supply from the well system would be cheaper, even if operated continnously.

The final estimates of cost of collecting the Suffolk County water have been increased to about $20 per million gallons delivered into the aqueduct, because of the allowances for infiltration basins and reservoirs on the salt-water estuaries, highways and other improvements on the right-of-way.

TIME REQUIRED FOR CONSTRUCTION OF WELLS AND GALLERIES

The construction of an infiltration gallery in a depth of ground-water from 10 to 20 feet takes much more time than required to put down the necessary wells in the same length of line. The Wantagh infiltration gallery, 12,300 feet in length, was built in two years, not including time lost in waiting for land. Construction was carried on at two points at a rate of about 200 feet per week. The Massapequa gallery,

TABLE 14

Relative Cost of a Supply from Wells and Galleries

Item	Infiltration Gallery Two Miles in Length: Based upon Bids on Massapequa Infiltration Gallery with Permanent pumping-station	Infiltration Gallery Two Miles in Length: Based on Suggested Design of Large Concrete Gallery	System of Stovepipe Wells Spaced 700 Feet Apart in Section Two Miles Long With Complete Pumping-System
Cost, without land or water damages...	$260,200	$403,000	$66,600
Gross lift..........................	43 feet	43 feet	50 feet
Average pumpage in million gallons daily..........................	10	10	10
Annual expenses:			
Fixed charges, including interest, sinking fund and taxes........	$13,160	$19,800	$3,254
Operating expenses, repairs and maintenance................	19,120	22,000	29,050
Extraordinary repairs and depreciation......................	4,701	2,400	3,375
Total.................	**$36,981**	**$44,200**	**$35,679**
Cost of water per million gallons delivered into aqueduct, without charges for land and water damages.	$10.13	$12.10	$9.78
Liberal estimate of cost of land for 1,000-foot right-of-way, and damages amounting altogether to $150,000 per mile........................	$300,000	$300,000	$300,000
Additional fixed charges for interest, sinking fund and taxes on this sum...	$16,000	$16,000	$16,000
Total cost of collecting water per million gallons, with charges for land and water damage................	*$14.51	*$16.48	*$14.16

*These prices include no charges for highways, fencing or other improvements proposed for the Suffolk County works, or any allowances for infiltration basins or reservoirs on the salt-water estuaries

which was begun in 1905, is not finished yet, after 2½ years. Work has generally been carried on at three points, although at times five gangs have been at work. Each gang has averaged about 60 feet per week.

An increase in the number of gangs means an increase in the cost of pumping, and it would not perhaps be reasonable to expect a contractor working on a section of gallery two miles in length to work at more than two points. Assuming a progress of 200 feet per week at both points and a working season of 40 weeks, two miles of gallery could not be completed in less than 1½ years, whereas the 15 wells proposed in the same length of line could be driven and completely equipped inside of six months. Considering the great need for water in Brooklyn and the short time in which the works in Suffolk county would need be built, when such works should be authorized, the greater speed of constructing the wells becomes a most important consideration.

COMPARATIVE MERITS OF WELLS AND INFILTRATION GALLERIES

The relative advantages of wells and infiltration galleries for the proposed Suffolk County collecting works, that have been stated in the preceding pages, may be briefly summarized as follows:

Advantages of a System of Wells

(1) Larger portion of entire yield can be collected.

(2) More ground-water storage readily available by deep pumping during periods of drought.

(3) Smaller cost of construction and fixed charges, which is important for works that may be idle a portion of year.

(4) Economy in first cost if only part of wells constructed.

(5) Greater speed of construction.

(6) More elasticity in operation and maintenance.

Advantages of an Infiltration Gallery

(1) No danger from inflow of sea-water when placed above sea-level.

(2) Economy in continuous operation at central pumping-station. (This is offset by high fixed charges on a gallery of permanent construction.)

Conclusions

The doubtful advantage of an infiltration gallery in providing greater safety from sea-water and the slightly lower cost of operating a gallery of the Brooklyn type, are more than outweighed by the advantages of a system of wells in providing a larger and more uniform supply, and the saving effected in time and in cost of construction. A system of wells is, therefore, proposed for the Suffolk County development.

WELL SYSTEM WITH GRAVITY FLOW TO AQUEDUCT

To avoid the high operating expenses in pumping a system of wells, it has been suggested that the masonry aqueduct be placed sufficiently low to permit the water from the wells to flow directly into it without pumping. This plan was adopted in 1884 on the Ursprung works of Nuremberg (Bavaria) and has now been in successful operation for 24 years. These works are situated, however, in a narrow and elevated mountain valley with a tight rock bottom where the conditions were favorable for this kind of construction. It is of interest to note that the works constructed later by the same city at Erlenstegen in the low valley of the Pegnitz were equipped with a pumping system.

Conditions in Southern Suffolk County

In western Suffolk county, where the conditions would be more favorable for a deep aqueduct than farther east, the general elevation of the ground-water on the line of the proposed collecting works is about Elevation 20 on the B. W. S. datum. To secure sufficient ground-water storage to maintain the supply, the ground-water would be drawn down to at least Elevation 5. Making a fair estimate of the loss in the wall of the well and in the connections to the aqueduct as five feet, the surface of the water in the aqueduct, where running full, should not be above Elevation 0. This would require the invert of the section proposed in western Suffolk county to be at Elevation—13.5, and the subgrade at about Elevation —15.

The surface of the ground in western Suffolk county will average 30 feet in elevation, and the total depth of excavation for the aqueduct would therefore average about 45 feet, of

which 35 feet would be in saturated sands. If, on the other hand, all wells were to be pumped, an aqueduct can be located in western Suffolk county, with the grade of the invert 30 feet above that required by a gravity inflow system.

In the easterly portion of the proposed line of collecting works and in the valleys of the larger streams, the ground-water is below Elevation 20, and unless the aqueduct were placed still lower than suggested, the wells on portions of the line would necessarily be pumped.

Preliminary estimates have been made on a continuous gravity aqueduct with its invert at the Nassau-Suffolk County line at Elevation 0, 13.5 feet above that just proposed. The estimates indicated that the fixed charges on the additional cost of placing the aqueduct at even this depth over that of constructing the aqueduct at the higher elevation recommended in this report, in connection with a pumping system, would be much greater than the saving in operating expenses effected by not pumping on portions of the line. The gravity inflow plan is, furthermore, open to one of the chief objections to the infiltration gallery in that it would be impossible with such a system to draw deeply upon the ground-water storage during brief periods of large demand. Altogether, this plan has no advantage to recommend it and has not been further considered.

LAND FOR COLLECTING WORKS

Width of Right-of-way

It is proposed to acquire on the entire line of the proposed collecting works, a strip of land 1,000 feet wide. The wells would be placed in the center of this right-of-way for the protection of the ground-water supply from subsurface pollution. Possibly a width of 600 feet would be sufficient where the property is expensive, but the greater width is believed to be desirable.

Subsurface Pollution

It is necessary to protect the works against the contamination that might come from cesspools and privies constructed near the proposed taking. Filth that is placed in the ground beyond the oxidizing action of the bacteria in the surface soil is not readily destroyed and if below the water-table may be carried some distance in coarse sand and gravel by the moving ground-water.

The incomplete experiments of the Burr-Hering-Freeman Commission near Elmont were not conclusive as regards the maximum distance through which pathogenic organisms may be carried to the wells of ground-water collecting works, since the subsoils where these experiments were made were fairly fine and the slope and velocity of the ground-water small. The experience at some of the German ground-water plants near the surface streams indicate that the collecting works should not perhaps be less than 200 to 300 feet from the river to secure complete bacterial purification of the surface waters. The right to dispose of household wastes in the ground is one that has been established by age-long usage. While it has been ruled in several states that a ground supply may not be polluted, it might not be so easy to remove such sources of pollution, as those mentioned above, as it is to protect a surface supply from contamination, and it would doubtless be expensive. The cost of a right-of-way 1,000 feet in width would not be proportionally greater than one 600 feet if purchased now, and it is believed the greater width should be adopted.

Relation of Wells to Aqueduct

The center of the aqueduct would be laid out 25 feet away from the wells to avoid disturbing the foundations of the aqueduct when constructing new wells or cleaning up old ones. On the main line in southern Suffolk county, the aqueduct would be placed north of the wells in order to give access to them from the highway proposed on the south side of the taking. The same relation of wells and highways would, of course, be adopted elsewhere.

For the Peconic Valley collecting works, it is proposed to acquire a strip of land along the south side of the Peconic river from Riverhead to Calverton, averaging 1,000 feet in width, and possibly later, if considered desirable, to purchase a strip on the north side and the river itself, in order to utilize the river as a natural infiltration basin for the development of the surface-waters as artificial ground-water.

Improvement of Right-of-Way

It is proposed to improve all the lands purchased for the collecting works, to soil and seed all highway and aqueduct slopes, both to protect the work as well as to make the right-

of-way attractive. A neat wire fence with iron or concrete posts is estimated about all the property to be acquired. In all the villages through which the works pass and where active real estate developments are being made, allowances are made in the estimates for grading, seeding, planting shrubs and trees, constructing gravel walks, and giving the right-of-way an appropriate landscape treatment. These sections would receive the same care as given park property within the City limits.

Throughout Suffolk county it is further proposed to build a wide macadam road on the south side of the right-of-way for convenience of operation of the works and the use of the public. This highway would give access to large areas now far from trunk highways and would add greatly to the attractiveness of the project. This highway is estimated to cost $10,000 per mile, exclusive of the grading, much of which could be done during the construction of the aqueduct by borrowing from the highway cuts and spoiling on the fills. It is also proposed to surface with macadam all public road crossings within the right-of-way.

OUTLINE OF COLLECTING WORKS

The conclusions reached in the above considerations on the methods of gathering the proposed Suffolk County ground-waters, permit the following outline of the collecting works to be made:

Method of Collection

The ground-water would be gathered by means of a continuous line of wells from 100 to 200 feet in depth, placed at short intervals in the center of a wide right-of-way 1,000 feet in width.

Type of Wells

The water would be collected in tubular wells of fairly large diameter, probably of the stovepipe type, penetrating the full depth of the yellow gravels, and provided with screen sections in all coarse strata.

Pumping System

The water would be drawn from these wells by some suitable form of deep well pump operated from one or more central power-stations.

TABLE 15

Geological Classification of Seaford Deep Well 10* Near Seaford Station, Long Island Railroad. Elevation, B. W. S. Datum: Surface of Ground, 24

Sample	Depth Feet	Character of Material
1	0 – 3	Yellow top-soil
2	3 – 7	" sand; small gravel
3	7 – 20	" " " "
4	20 – 25	Coarse light yellow sand; gravel
5	25 – 40	" " " " "
6	40 – 52	Gray sand; fine gravel; traces of clay; some Muscovite (white mica)
7	52 – 65	Dark gray clay; traces of gravel
8	65 – 68	Coarse gray sand; shells and gravel; shells abundant
9	68 – 72	Fine gray sand; Muscovite
10	72 – 82	Light gray sand; some lignite
11	82 – 91	Shells; clay and fine gravel; shells abundant; lignite
12	91–113	Dark gray clay; fine gravel; some shells
13	113–120	White sand; Muscovite; much lignite
14	120–135	Coarse white sand; Muscovite
15	135–154	" " " " lignite
16	154–167	Finer " " " much lignite
17	167–173	" " " " traces of lignite
18	173–179	" " " fine gravel with frags; shells
19	179–205	Fine " " Muscovite
20	205–245	" " " "
21	245–328	" " " " traces of lignite
22	328–535	" " " " some lignite
23	535–538	Coarse white sand; traces of clay and lignite
24	538–589	Fine white sand; traces of clay; some lignite
25	589–605	Coarse white sand; Muscovite; some lignite
26	605–608	Very coarse white sand; Muscovite
27	608–608.6	Gravel; white clay; lignite; purite
28	608.6–620	Coarse white sand; traces of clay; lignite; Muscovite
29	620–630	Fine white sand; fine gravel; traces of lignite
30	630–640	Coarse white sand; traces of clay and lignite
31	640–650	Coarse gray sand; fine gravel; traces of clay and lignite; Muscovite
32	650–660	Fine white sand; traces of clay and lignite; Muscovite
33	660–671	Fine and coarse gray sand
34	671–681	Very fine white sand; traces of lignite; Muscovite
35	681–685	White sand; fine gravel; traces of lignite; Muscovite
36	685–686	Light gray clay; some gravel
37	686–692	Very fine white sand; traces of lignite; Muscovite
38	692–700	Gray sand and gravel; some gray clay; lignite
39	700–710	Fine white sand; white clay; lignite; Muscovite
40	710–714	" " " traces of lignite
41	714–720	Coarse white sand; trace of lignite and clay; Muscovite
42	720–730	Gray gravel; sand; clay; no lignite
43	730–742	" " coarse sand; trace of clay and lignite
44	742–752	" " " " " " " "
45	752–772	" " some clay; no lignite
46	772–782	" " " " " "
47	782–792	" " no clay; no lignite
48	792–803	" " white sand; no clay; no lignite
49	803–805	" " trace of white clay; white sand
50	805–807	White clay; some sand
51	807–813	Gray gravel; some gray clay; lignite
52	813–820	Fine gray gravel; fine sand; lignite
53	820–830	White clay with some gravel and lignite
54	830–885	Medium and fine white sand; abundant lignite; Muscovite
55	885–945	" " " " " " " " "
56	945–972	" " " " " traces of " "
57	972–980	Very fine white sand; traces of lignite; Muscovite
58	980–985	" " " " " " " "
59	985–995	Fine white sand; some lignite; abundant Muscovite
60	995–1012	Very fine white sand; trace of lignite; abundant Muscovite

Continuous bed of gravel from about 715 to 805 = 90 feet. The white clay probably occurs in occasional thin layers or partings and is not disseminated through the gravel. Hence, the gravel is highly water bearing, and while passing through this gravel the well gave a continuous artesian flow.

*Classification of this well by Professor W. O. Crosby.

TABLE 15 (*Continued*)

Classification of Samples from Test-well 537, Amityville, Long Island. Well 101 Feet in Depth, 2 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 33.5; Bottom, —66.3; Ground-water, 20.7

Sample	Depth Feet	Character of Material
1	0 – 12	Fine gravel 20 per cent.; yellow sand: coarse 45 per cent.; medium 30 per cent.; loam 5 per cent.
2	12 – 19	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
3	19 – 25	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
4	25 – 31	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
5	31 – 38	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
6	38 – 44	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
7	44 – 51	Fine gravel 10 per cent.; yellow sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
8	51 – 57	Fine gravel 10 per cent.; yellow sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
9	57 – 62	Fine gravel 10 per cent.; yellow sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
10	62 – 67	Fine gravel 10 per cent.; yellow sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
11	67 – 72	Fine gravel 40 per cent.; yellow gray superfine sand 60 per cent.
12	72 – 78	" " 5 " " " " " 95 "
13	78 – 83	Yellow gray sand: medium 20 per cent.; fine 30 per cent.; superfine 50 per cent.
14	83 – 88	Yellow gray sand: medium 20 per cent.; fine 30 per cent.; superfine 50 per cent.
15	88 – 93	Yellow gray sand: coarse 40 per cent.; medium 40 per cent.; fine 20 per cent.
16	93 – 101	Fine gravel 20 per cent.; yellow sand: medium 20 per cent.; fine 60 per cent.; trace of peat

Classification of Samples from Test-well 574, Lindenhurst, Long Island. Well 101 Feet in Depth, 2 Inches in Diameter

Sample	Depth Feet	Character of Material
1	0 – 7	Fine gravel 40 per cent.; white sand: coarse 40 per cent.; medium 20 per cent.
2	7 – 13	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
3	13 – 20	Fine gravel 80 per cent.; yellow sand: coarse 20 per cent.; trace of peat
4	20 – 26	Gravel: coarse 60 per cent.; fine 20 per cent.; coarse sand 20 per cent.
5	26 – 33	Yellow sand: coarse 20 per cent.; medium 40 per cent.; fine 40 per cent.
6	33 – 38	Yellow sand: medium 60 per cent.; fine 40 per cent.
7	38 – 43	" " " 60 " " " 40 " "
8	43 – 47	" " " 60 " " " 40 " "
9	47 – 53	Yellow sand: medium 20 per cent.; fine 40 per cent.; superfine 40 per cent.
10	53 – 58	Fine gravel 40 per cent.; brown sand: coarse 40 per cent.; medium 20 per cent.
11	58 – 63	Trace of clay; black superfine sand; trace of peat
12	63 – 68	" " " " " " " " "
13	68 – 73	Trace of clay; gray sand: coarse 20 per cent.; medium 20 per cent.; fine 60 per cent.; trace of peat
14	73 – 78	Trace of clay; gray superfine sand
15	78 – 83	Hard blue dry clay
16	83 – 87	Blue clay and rock-flour
17	87 – 93	" " 50 per cent.; superfine sand 50 per cent.
18	93 – 101	" " 80 " " sand 20 per cent.

TABLE 15 (*Continued*)

Classification of Samples from California Stovepipe Well 4, Experiment Station, Lindenhurst, Long Island, 14 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 30; Ground-water, 22.3

Sample	Depth Feet	Character of Material
1	0 – 2.5	Brown clay intermixed with sand and vegetable matter
2	2.5 – 5	Gravel 5 per cent.; loam 75 per cent.; sand 20 per cent.
3	5 – 6	" 12 " " sand 88 " "
4	6 – 9	" 15 " " " 85 " "
5	9 – 11	Gravel: coarse 10 per cent.; fine 5 per cent.; sand 85 per cent.
6	11 – 13	" " 10 " " " 5 " " " 85 " "
7	13 – 15	" " 20 " " " 10 " " " 70 " "
8	15 – 17	" " 70 " " " 10 " " " 20 " "
9	17 – 19	" " 30 " " " 20 " " " 50 " "
10	19 – 21	" " 60 " " " 20 " " " 20 " "
11	21 – 23	" " 50 " " " 30 " " " 20 " "
12	23 – 25	" " 25 " " " 60 " " " 15 " "
13	25 – 27	" " 20 " " " 30 " " " 50 " "
14	27 – 29	" " 30 " " " 30 " " " 40 " "
15	29 – 31	" " 20 " " " 20 " " " 60 " "
16	31 – 33	" " 50 " " " 30 " " " 20 " "
17	33 – 35	" " 20 " " " 20 " " " 60 " "
18	35 – 37	" " 5 " " " 50 " " " 45 " "
19	37 – 39	" " 20 " " " 25 " " " 55 " "
20	39 – 41	Gravel 5 per cent.; sand: coarse 20 per cent.; medium 50 per cent.; fine 25 per cent.
21	41 – 45	Gravel: coarse 5 per cent.; fine 15 per cent.; sand 80 per cent.
22	45 – 47	" " 40 " " " 50 " " " 10 " "
23	47 – 49	" " 10 " " " 15 " " " 75 " "
24	49 – 51	Gravel 10 per cent.; sand: coarse 10 per cent.; medium 40 per cent.; fine 40 per cent.
25	51 – 53	Gravel: coarse 10 per cent.; fine 10 per cent.; sand: coarse 40 per cent.; medium 20 per cent.; fine 20 per cent.
26	53 – 55	Gravel: coarse 10 per cent.; fine 10 per cent.; sand: coarse 40 per cent.; medium 20 per cent.; fine 20 per cent.
27	55 – 57	Gravel 10 per cent.; sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
28	57 – 59	Gravel: coarse 20 per cent.; fine 30 per cent.; sand: coarse 30 per cent.; medium 15 per cent.; fine 5 per cent.
29	59 – 61	Gravel: coarse 20 per cent.; fine 30 per cent.; sand: coarse 30 per cent.; medium 15 per cent.; fine 5 per cent.
30	61 – 63	Gravel: coarse 30 per cent.; fine 30 per cent.; sand 40 per cent.
31	63 – 65	" " 25 " " " 15 " " " 60 " "
32	65 – 67	" " 10 " " " 5 " " sand: coarse 10 per cent.; medium 25 per cent.; fine 50 per cent.
33	67 – 69	Gravel: coarse 5 per cent.; fine 5 per cent.; sand: coarse 20 per cent.; medium 40 per cent.; fine 30 per cent.
34	69 – 71	Gravel: coarse 5 per cent.; fine 5 per cent.; sand: coarse 20 per cent; medium 40 per cent.; fine 30 per cent.
35	71 – 73	Gravel: coarse 20 per cent.; fine 30 per cent.; sand: 50 per cent.; ironrust
36	73 – 75	Sand: coarse 20 per cent.; medium 20 per cent.; fine 10 per cent.; gravel 10 per cent.; brown clay 40 per cent.
37	75 – 77	Gravel 5 per cent.; sand 85 per cent.; brown clay 10 per cent.
38	77 – 79	" 10 " " " 80 " " sandstone 10 per cent.
39	79 – 84	Gravel 5 per cent.; sand 45 per cent.; clay 30 per cent.; peat; sandstone
40	84 – 90	Fine gray sand; peat
41	84 – 90	" " " " black clay
42	90 – 96	" " " black clay
43	96 – 102	" " " " "
44	102 – 108	" " " peat
45	108 – 114	" " " black clay; peat
46	114 – 120	" " " peat; mica
47	120 – 126	Hard black clay
48	126 – 135	" " "

TABLE 15 (*Continued*)

Well 4 (*Concluded*)

Sample	Depth Feet	Character of Material
49	135–141	Fine gray sand; peat; mica
50	141–147	" " " " "
51	147–153	" " " " "
52	153–159	" " " " "
53	159–165	" " " " "
54	165–171	" " " " "
55	171–177	" " " 95 per cent.; clay 5 per cent.
56	177–183	" " " peat; mica
57	183–187	" " " " "
58	187–189	" " " " "
59	189–199	Hard black clay
60	199–205	Fine gray sand; peat; mica
61	205–209	" " " " "
62	209–215.5	Hard black clay
63	215.5–221	Fine gray sand; peat; mica
64	221–227	" " " " "
65	227–233	" " " " "
66	233–237	" " " " "
67	237–243	" " " " "
68	243–251.5	" " " " "
69	251.5–255	Hard black clay
70	255–261	Fine gray sand; peat; mica
71	261–268	Hard black clay
72	268–274	Fine gray sand; peat; mica
73	274–280	" " " " "
74	280–287	" " " " "
75	287–293	" " " " "
76	293–297.5	" " " " "
77	297.5–304	Hard black clay
78	304–310	Fine gray sand; peat; mica
79	310–315	" " " " "
80	315–321	" " " " "
81	321–327	Black clay intermixed with lignite
81a	321–327	Fine gray sand; hard black clay; peat
82	327–333	" " " peat; mica
83	333–339	" " " " "
84	339–345	" " " " "
85	345–351.5	" " " " "
86	351.5–354.5	Hard black clay
87	354.5–360	Fine gray sand; peat; mica
88	360–370	" " " black clay ; sandstone

TABLE 15 (*Continued*)

CLASSIFICATION OF SAMPLES FROM TEST-WELL 576, WYANDANCH, LONG ISLAND. WELL 125 FEET IN DEPTH, 2 INCHES IN DIAMETER

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 6	Fine gravel 80 per cent.; yellow sand: coarse 10 per cent.; loam 10 per cent.
2	6 – 12	Fine gravel 80 per cent.; yellow sand: coarse 20 per cent.; trace of loam
3	12 – 19	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; fine 20 per cent.
4	19 – 25	Fine gravel 80 per cent.; yellow sand: coarse 20 per cent.
5	25 – 32	Gravel: coarse 40 per cent.; fine 40 per cent.; yellow coarse sand 20 per cent.
6	32 – 38	Gravel: coarse 40 per cent.; fine 40 per cent.; yellow coarse sand 20 per cent.
7	38 – 44	Fine gravel 40 per cent.; yellow coarse sand 60 per cent.
8	44 – 50	" " 40 " " " " " 60 " "
9	50 – 57	" " 40 " " " " " 60 " "
10	57 – 62	Fine gravel 10 per cent.; yellow sand: coarse 40 per cent.; medium 50 per cent.
11	62 – 68	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
12	68 – 73	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
13	73 – 78	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
14	78 – 83	Fine gravel 80 per cent.; yellow coarse sand 20 per cent.
15	83 – 88	" " 40 " " " " " 60 " "
16	88 – 93	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
17	93 – 97	Blue clay
18	97–100	Yellow sand: coarse 40 per cent.; medium 60 per cent.
19	100–105	Light gray superfine sand; trace of peat
20	105–110	" " " " " " "
21	110–115	" " " " " " "
22	115–120	White fine sand 100 per cent.; trace of peat
23	120–125	" " " 100 " " " " "

TABLE 15 (*Continued*)

Classification of Samples from California Stovepipe Well 5, Experiment Station, Wyandanch, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 56; Ground-water, 51

Sample	Depth Feet	Character of Material
1	0 – 1	Loam 80 per cent.; gravel 20 per cent.
2	1 – 4	Gravel: coarse 75 per cent.; fine 15 per cent.; sand 10 per cent.
3	4 – 6	Gravel 15 per cent.; sand: coarse 20 per cent.; medium 20 per cent.; fine 45 per cent.
4	6 – 10	Gravel: coarse 30 per cent.; fine 15 per cent.; sand 55 per cent.
5	10 – 15	Gravel 25 per cent.; sand: coarse 30 per cent.; medium 25 per cent.; fine 20 per cent.
6	15 – 18	Gravel: coarse 10 per cent.; fine 10 per cent.; sand 80 per cent.
7	18 – 20	" " 25 " " " 25 " " " 50 " "
8	20 – 22	" " 20 " " " 10 " " " 70 " "
9	22 – 24	" " 40 " " " 20 " " " 40 " "
10	24 – 26	" " 30 " " " 10 " " " 60 " "
11	26 – 28	" " 10 " " " 5 " " " 85 " "
12	28 – 30	" " 15 " " " 10 " " " 75 " "
13	30 – 32	" " 10 " " " 10 " " " 80 " "
14	32 – 34	" " 20 " " " 30 " " " 50 " "
15	34 – 36	Gravel 25 per cent.; sand: coarse 10 per cent.; medium 35 per cent.: fine 30 per cent.
16	36 – 38	Gravel: coarse 5 per cent.; fine 40 per cent.; sand 55 per cent.
17	38 – 40	" " 60 " " " 30 " " " 10 " "
18	40 – 42	" " 30 " " " 40 " " " 30 " "
19	42 – 44	" " 10 " " " 30 " " " 60 " "
20	44 – 46	" " 50 " " " 5 " " " 45 " "
21	46 – 48	Gravel 25 per cent.; sand: coarse 25 per cent.; medium 35 per cent.; fine 15 per cent.
22	48 – 50	Gravel: coarse 30 per cent.; fine 30 per cent.; sand 40 per cent.
23	50 – 52	" " 50 " " " 40 " " " 10 " "
24	52 – 54	" " 30 " " " 30 " " " 40 " "
25	54 – 56	Gravel 30 per cent.; sand: coarse 30 per cent.; medium 30 per cent.; fine 10 per cent.
26	56 – 58	Gravel: coarse 10 per cent.; fine 10 per cent.; sand 80 per cent.
27	58 – 60	" " 50 " " " 30 " " " 20 per cent.
28	60 – 62	" " 80 " " " 20 " "
29	62 – 64	" " 70 " " " 25 " " brown clay 5 per cent.
30	64 – 66	Gravel 30 per cent.; sand: coarse 50 per cent.; medium 15 per cent.; fine 5 per cent.
31	66 – 68	Gravel 25 per cent.; sand: coarse 60 per cent.; medium 15 per cent.
32	68 – 70	Gravel 20 per cent.; sand 70 per cent.; clay 10 per cent.
33	70 – 72	Sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
34	72 – 74	Sand: coarse 30 per cent.; medium 30 per cent.; fine 10 per cent.; gravel: coarse 20 per cent.; fine 10 per cent.
35	74 – 76	Brown clay; few small pebbles
36	76 – 78	Hard black clay
37	78 – 81	" " "
38	81 – 83.5	Fine gray sand
39	83.5 – 86	Hard black clay
40	86 – 88	Sand: medium 75 per cent.; fine 25 per cent.
41	88 – 92	Fine gravel 5 per cent.; sand 25 per cent.; sandstone 10 per cent.; brown clay 60 per cent.
42	92 – 94	Brown clay stratified with peat and mica
43	94 – 96	Brown clay 50 per cent.; fine brown sand 50 per cent.
44	96 – 98	Sand: medium 60 per cent.; fine 40 per cent.
45	98 – 99.5	Brown clay
46	99.5 – 100.5	Peat mixed with fine sand
47	100.5 – 104	Brown clay
48	104 – 108	Fine brown sand
49	108 – 112	" " "
50	112 – 118	" " "
51	118 – 124	Brown clay 10 per cent.; fine brown sand 90 per cent.
52	124 – 130	Sandstone 10 per cent; fine sand 50 per cent.; brown clay 40 per cent.
53	130 – 136	Fine brown sand
54	136 – 142	" " "

TABLE 15 (*Continued*)

Well 5 (*Concluded*)

Sample	Depth Feet	Character of Material
55	142–148	Sandstone 10 per cent.; fine brown sand 90 per cent.
56	148–149	Hard brown clay
57	149–152	Hard black clay
58	152–159	Soft brown clay; pyrite
59	159–164	Fine gray and brown sand mixed
60	164–170	" " " " " "
61	170–176	Fine brown sand
62	176–180	" " "
63	180–184	Sandstone; fine sand
64	184–190	Fine brown sand
65	190–196	" " "
66	196–202	" " "
67	202–208	" " "
68	208–214	" " "
69	214–220	" " " 90 per cent.; brown clay 10 per cent.
70	220–226	" " "
71	226–232	" " "
72	232–238	" " "
73	238–242	" " "
74	242–243	Red and gray clay stratified
75	243–249	Fine brown sand
76	249–251	Brown clay mixed with fine sand
77	251–254	Hard black clay
78	254–260	Fine brown sand
79	260–266	" " "
80	266–272	" " "
81	272–278	" " "
82	278–284	" " "
83	284–290	" " "
84	290–296	" " "
85	296–302	" gray "
86	302–308	" " "
87	308–314	" " "
88	314–320	" " "
89	320–327	" " "
90	327–328	Black clay stratified with peat; pyrites
91	328–331	Hard black clay; peat
92	331–336	" " " "
93	336–342	Blue gray clay
94	342–348	" " "
95	348–356	Fine gray sand; mica flakes
96	356–361	Soft black clay intermixed with peat
97	361–367	Fine gray sand; peat
98	367–373	" " " mica flakes
99	373–379	" " " peat
100	379–385	" " " "
101	385–391	" " " "
102	391–400	Hard black clay

TABLE 15 (*Continued*)

Classification of Samples from Test-well 511, Babylon, Long Island. Well 102 Feet in Depth, 2 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 17.8

Sample	Depth Feet	Character of Material
1	0 – 7	Fine gravel 60 per cent.; gray sand: coarse 30 per cent.; medium 10 per cent.
2	7 – 13	Fine gravel 60 per cent.; gray sand: coarse 30 per cent.; medium 10 per cent.
3	13 – 19	Yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.
4	19 – 26	Yellow sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
5	26 – 33	Yellow sand: medium 60 per cent.; fine 40 per cent.
6	33 – 38	" " " 60 " " " 40 " "
7	38 – 44	" " " 60 " " " 40 " "
8	44 – 50	Gray sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
9	50 – 56	Gray sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
10	56 – 63	Gray sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
11	63 – 69	Gray sand: coarse 10 per cent.; medium 30 per cent.; fine 40 per cent.; superfine 20 per cent.
12	69 – 73	Gray superfine sand 100 per cent.; trace of peat
13	73 – 81	Light gray superfine sand 100 per cent.; trace of peat
14	81 – 85	" " " " 100 " " " " "
15	85 – 90	" " " " 100 " " " " "
16	90 – 93	Dark gray superfine sand 70 per cent.; peat 30 per cent.
17	93 – 95	Light gray sand: fine 70 per cent.; superfine 30 per cent.
18	95 – 99	" " " " 30 " " " 70 " "
19	99-102	" " superfine sand 100 per cent; trace of peat

TABLE 15 (*Continued*)

Classification of Samples from California Stovepipe Well 1, Experiment Station, West Islip, Long Island, 14 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 33.4; Ground-water, 23.9

Sample	Depth Feet	Character of Material
1	0 – 3	Top-soil; medium and fine sand mixed with fine clay and fine gravel
2	3 – 9	Gravel: coarse 20 per cent.; fine 10 per cent.; coarse sand 70 per cent.
3	9 – 12	Coarse gravel 50 per cent.; coarse sand 50 per cent.
4	12 – 17	Gravel 70 per cent.; sand 30 per cent.
5	17 – 21	" 80 " " sand: coarse 10 per cent.; medium 10 per cent.
6	21 – 38	Fine gravel 10 per cent.; yellow sand: medium 65 per cent ; fine 25 per cent.
7	21 – 38	Fine gravel 10 per cent.; yellow sand: medium 65 per cent.; fine 25 per cent.
8	38 – 54	Fine gravel 10 per cent; yellow sand: medium 65 per cent.; fine 25 per cent.
9	54 – 60	Coarse gravel 15 per cent.; yellow sand: medium 55 per cent.; fine 30 per cent.
10	60 – 70	Coarse gravel 5 per cent.; yellow sand: medium 45 per cent.; fine 50 per cent.
11	70 – 75	Fine gravel 5 per cent.; yellow sand: medium 60 per cent.; fine 35 per cent.
12	75 – 80	Fine gravel 5 per cent.; yellow sand: medium 60 per cent.; fine 35 per cent.
13	80 – 88	Yellow sand: coarse 5 per cent.; medium 50 per cent.; fine 40 per cent.; organic matter 5 per cent.
14	88 – 94	Gravel: coarse 25 per cent.; fine 10 per cent.; yellow sand: coarse 10 per cent.; medium 55 per cent.
15	94 – 97	Gravel: coarse 30 per cent.; fine 40 per cent.; yellow sand: coarse 20 per cent.; medium 10 per cent.
16	97 – 98	Gravel: coarse 70 per cent.; fine 20 per cent.; coarse yellow sand 10 per cent.
17	98–102	Mixture of fine gravel, sand and clay with iron-coated pyrites
18	102–104	Dark blue clay with pyrites
19	104–106	Sand: fine 70 per cent.; superfine 30 per cent.
20	106–113	" " 40 " " " 60 " "
21	113–115	" medium 70 per cent.; fine 30 per cent.
22	115–116	Black clay well compacted
23	116–117	" " " "
24	117–119	Sand: fine 60 per cent.; superfine 40 per cent.
25	119–131	" medium 75 per cent.; fine 25 per cent.; pyrites; peat
26	119–131	" " 75 " " " 25 " " " "
27	119–131	" " 75 " " " 25 " " " "
28	131–135	Dark clay stratified with fine sand and peat
29	135–136	" " " " " " " "
30	136–138	" " " " " " " "
31	138–146	Sand: medium 70 per cent.; fine 30 per cent.
32	146–147	Mixture of organic matter, gray clay and fine sand inter-stratified
33	147–149	Coarse sand mixed with light gray clay; layer of pyrites with sand
34	149–156	Mixture of dark blue sand with peat and medium sand
35	149–156	" " " " " " " " " "
36	156–160	Sand: coarse 30 per cent.; medium 70 per cent.
37	160–164	Slimy mixture of gray clay with peat
38	164–170	Sand: medium 80 per cent.; fine 20 per cent.
39	170–173	" " 90 " " " 10 " "
40	173–174	Medium gray sand mixed with pyrites
41	174–175	Peat
42	175–182	Sand: medium 30 per cent.; fine 70 per cent.
43	182–187	Medium and fine gray sand with small layer of stratified peat
44	187–205	Sand: medium 25 per cent.; fine 75 per cent.
45	205–207	Mixture of gray sand, clay and peat
46	207–208	Fine gravel 3 per cent.; sand: coarse 60 per cent.; medium 30 per cent.; clay 7 per cent.
47	207–208	Fine gravel 3 per cent.; sand: coarse 60 per cent.; medium 30 per cent.; clay 7 per cent.
48	207–208	Fine gravel 3 per cent.; sand: coarse 60 per cent.; medium 30 per cent.; clay 7 per cent.
49	208–209	Black clay with traces of sand
50	209–210	" " " " " "

TABLE 15 (*Continued*)

Well 1 (*Continued*)

Sample	Depth Feet	Character of Material
51	210–212.5	Black clay 20 per cent.; sand: coarse 60 per cent.; medium 10 per cent.; fine 10 per cent.
52	212.5–214	Black clay with fine sand and peat
53	214–217	Medium and fine sand with pyrites
54	217–221	Sand: coarse 10 per cent.; medium 70 per cent.; fine 20 per cent.
55	221–224.5	" medium 60 per cent.; fine 30 per cent.; peat 10 per cent.
56	224.5–228	Soft stratified gray clay
57	224.5–228	" " " "
58	224.5–228	" " " "
59	225.5–228	" " " "
60	228–230	Soft and fine gray clay; pyrites
61	230–234	" " " " " "
62	230–234	" " " " " "
63	234–236.5	Gray clay
64	236.5–238.5	" "
65	238.5–240	" "
66	240–243	" "
67	243–244.5	Sand: medium 70 per cent.; fine 30 per cent.
68	244.5–246	Medium sand, peat and pyrites
69	244.5–246	" " " "
70	246–249	Dark gray and white clay with pyrites and medium sand
71	249–253.5	Gray clay mixed with sand, firmly compacted
72	253.5–254.5	" " " " " " "
73	254.5–256.5	" " " " " " "
74	256.5–258.5	Black fine clay
75	258.5–259	" " " with peat
76	259–260	Dark gray clay and pyrites
77	260–261	Black clay, pyrites and peat
78	261–264	Sand: medium 60 per cent.; fine 35 per cent.; clay 5 per cent.
79	264–267	" " 60 " " " 40 " "
80	267–270	" " 60 " " " 40 " "
81	270–271	Stratified layer of peat and clay
82	271–274	Sand: medium 70 per cent.; fine 30 per cent.; pyrites
83	274–281	Medium and fine light gray sand with peat and clay
84	274–281	" " " " " " " " " "
85	281–285	Medium sand; pyrites
86	285–287	Gray clay; medium sand; peat; pyrites
87	287–292	Sand: medium 70 per cent.; fine 30 per cent.
88	292–300	" " 70 " " " 30 " "
89	300–305	" " 70 " " " 30 " "
90	305–314.5	" " 70 " " " 30 " "
91	314.5–317	Peat with medium gray sand
92	317–323	Sand: medium 85 per cent.; fine 15 per cent.
93	323–326	Layers of black soft clay and fine sand
94	326–327	" " " " " " " "
95	327–330	Light gray clay inter-stratified with fine sand and peat
96	327–330	" " " " " " " " " " "
97	330–332	Medium sand 90 per cent.; clay 10 per cent.
98	332–339.5	Soft black clay inter-stratified with peat and sand
99	339.5–342	Clay; pyrites; peat
100	342–344.5	" " "
101	344.5–345.5	Clay; peat; medium sand
102	345.5–353	" " " "
103	353–355	Clay 85 per cent.; fine sand 15 per cent.
104	355–358	Soft black clay mixed with peat and fine sand
105	355–358	" " " " " " " "
106	358–364.5	Sand: medium 70 per cent.; fine 30 per cent.; traces of clay
107	364.5–369	Medium and fine sand mixed with clay and pyrites
108	369–370	Pyrites and micaceous sandstone
109	370–372	Medium sand and impure pyrites
110	372–379	Sand: medium 70 per cent.; fine 30 per cent.
111	379–382	" " 40 " " " 40 " " clay 20 per cent.
112	382–388	" " 40 " " " 40 " " " 20 " "
113	388–394	" " 40 " " " 40 " " " 20 " " with pyrites
114	388–394	Sand: medium 40 per cent.; fine 40 per cent.; clay 20 per cent. with pyrites
115	394–400	Medium sand 70 per cent.; clay 30 per cent.; pyrites; peat
116	394–400	" " 70 " " " 30 " " " "
117	400–401	Small fragments of pyrites and peat with traces of clay
118	401–405.5	Clay 70 per cent.; pyrites 20 per cent.; peat 10 per cent.
119	401–405.5	" 70 " " " 20 " " " 10 " "
120	401–405.5	" 70 " " " 20 " " " 10 " "

TABLE 15 (*Continued*)

Well 1 (*Continued*)

Sample	Depth Feet	Character of Material
121	405.5–408	Medium sand 80 per cent.; clay 20 per cent. ; peat
122	405.5–408	" " 80 " " " 20 " " "
123	408–409	Clay
124	409–410	"
125	409–410	"
126	410–411	Peat; sand; clay
127	411–412	Clay 95 per cent.; sand 5 per cent.
128	412–413	Pyrites 15 per cent.; clay 70 per cent.; sand 15 per cent.
129	413–416	Clay with fine sand
130	416–418	" peat; fine sand
131	418–421	"
132	421–426	Clay 60 per cent.; fine sand 30 per cent.; pyrites 5 per cent.; peat 5 per cent.
133	426–431	Medium sand and peat inter-stratified; pyrites
134	426–431	" " " " " " "
135	431–434	Medium sand 60 per cent.; clay 30 per cent.; pyrites 5 per cent.; peat 5 per cent.
136	434–440	Medium sand 60 per cent.; clay 30 per cent.; pyrites 5 per cent.; peat 5 per cent.
137	440–444	Medium sand 80 per cent.; fine sand 15 per cent.; clay, pyrites and peat 5 per cent.
138	444–450	Medium sand 80 per cent.; fine sand 15 per cent.; clay, pyrites and peat 5 per cent.
139	450–455	Clay 60 per cent.; fine sand 30 per cent.; peat 10 per cent.
140	450–455	" 60 " " " " 30 " " " 10 " "
141	455–461	Gray soft clay; medium sand; pyrites; peat
142	461–466	Medium sand and pyrites
143	466–469	" " light gray clay; peat; pyrites
144	469–473	" " " " " " "
145	473–476	" " " " " " "
146	476–481	Sand: medium 60 per cent.; fine 35 per cent.; pyrites and peat 5 per cent.
147	481–486	Sand: medium 30 per cent.; fine 40 per cent.; clay 25 per cent.; pyrites and peat 5 per cent.
148	486–489	Medium sand 80 per cent.; clay 20 per cent.; pyrites
149	489–492	" " 80 " " " 20 " " " with peat
150	492–497.5	Sand: medium 75 per cent.; fine 20 per cent.; pyrites and peat 5 per cent.
151	497.5–508	Sand: medium 75 per cent.; fine 20 per cent.; pyrites and peat 5 per cent.
152	508–510	Sand: medium 75 per cent.; fine 20 per cent.; pyrites and peat 5 per cent.
153	510–512	Sand: medium 60 per cent.; fine 40 per cent.; traces of pyrites
154	512–515	Sand: medium 30 per cent.; fine 55 per cent.; hard gray clay 15 per cent.
155	515–517.5	Fine sand 80 per cent.; soft gray clay 20 per cent.; pyrites
156	517.5–520	Medium sand 60 per cent.; fine gray sand 40 per cent.
157	520–524.5	Fine sand and pyrites
158	524.5–529	Gray clay 60 per cent.; medium sand 40 per cent.
159	529–530.5	Large pieces of pyrite and clay
160	530.5–534	" " " " " "
161	534–537	Sand: medium 50 per cent.; fine 40 per cent.; gray clay 10 per cent.
162	537–540	Sand: medium 50 per cent.; fine 40 per cent.; gray clay 10 per cent.
163	540–542	Sand: medium 70 per cent.; fine 15 per cent.; gray clay and peat 15 per cent.
164	542–545	Sand: medium 70 per cent.; fine 15 per cent.; gray clay and peat 15 per cent.
165	545–550	Peat interlaid with mica and clay, with medium sand
166	550–554	Sand: medium 30 per cent.; fine 60 per cent.; clay and mica 10 per cent.
167	554–558	Sand: medium 30 per cent.; fine 60 per cent.; clay and mica 10 per cent.
168	558–564	Sand: medium 20 per cent.; fine 75 per cent.; light gray clay 5 per cent.
169	564–565	Gray and brown and white clay; fine sand
170	565–567.5	Hard gray clay; pyrites
171	567.5–568.5	Hard gray clay; pyrites
172	568.5–572	" " " " peat

TABLE 15 (*Continued*)

Well 1 (*Continued*)

Sample	Depth Feet	Character of Material
173	572–573	Dark and light gray clay stratified; peat; medium and fine sand
174	573–575	" " " " " " " " " "
175	575–579.5	Coarse and medium sand; traces of fine gravel and clay
176	579.5–582.5	Sand: medium 30 per cent.; fine 50 per cent.; gray clay 20 per cent.; peat; mica
177	582.5–584.5	Sand: medium 20 per cent.; fine 70 per cent.; dark gray clay 10 per cent.
178	584.5–587	Particles of peat 70 per cent.; fine sand 25 per cent.; mica and clay 5 per cent.
179	584.5–587	Particles of peat 70 per cent.; fine sand 25 per cent.; mica and clay 5 per cent.
180	587–591	Fine gravel 5 per cent.; sand: coarse 60 per cent.; medium 20 per cent.; gray clay 15 per cent.
181	587–591	Fine gravel 5 per cent.; sand: coarse 60 per cent.; medium 20 per cent.; gray clay 15 per cent.
182	587–591	Fine gravel 5 per cent.; sand: coarse 60 per cent.; medium 20 per cent.; gray clay 15 per cent.
183	591–593	Gravel 10 per cent.; sand: coarse 20 per cent.; medium 40 per cent.; fine 30 per cent.; peat; clay
184	593–600	Fine gravel 10 per cent.; sand: coarse 60 per cent.; medium 20 per cent.; clay, peat and pyrites 10 per cent.
185	600–605	Gray clay 85 per cent.; sand 15 per cent.
186	605–607	Fine gray clay; sand
187	607–608	White clay; fine sand
188	608–611	Sand: medium 30 per cent.; fine 70 per cent.
189	611–616.5	" " 30 " " " 70 " "
190	616.5–617	Hard gray clay well compacted
191	617–619	Fine sand 80 per cent.; gray clay 20 per cent.
192	619–623	" " 80 " " " " 20 " "
193	623–624.5	" " 80 " " " " 20 " "
194	624.5–626	" " 80 " " " " 20 " "
195	626–628	Sand: medium 40 per cent.; fine 50 per cent.; clay 10 per cent.
196	628–631.5	Sand: medium 40 per cent.; fine 45 per cent.; clay 12 per cent.; peat 3 per cent.
197	631.5–642.5	Sand: medium 40 per cent.; fine 45 per cent.; clay 12 per cent.; peat 3 per cent.
198	642.5–646	Sand: medium 50 per cent.; fine 40 per cent.; clay 10 per cent.; peat
199	646–650	Sand: medium 40 per cent.; fine 50 per cent.; clay 10 per cent.; peat
200	650–652.5	Sand: coarse 20 per cent ; medium 60 per cent.; fine 15 per cent.; clay 5 per cent.
201	652.5–653.5	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 50 per cent.; clay 5 per cent.; peat
202	653.5–655.5	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 50 per cent.; clay 5 per cent.; peat
203	655.5–658	Traces of coarse and fine gravel; coarse and medium sand; clay and peat
204	658–660	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 40 per cent.; clay 15 per cent.
205	660–670	Sand: coarse 50 per cent.; medium 40 per cent.; fine 10 per cent.; trace of gravel
206	670–678	Sand: medium 30 per cent.; fine 60 per cent.; clay 10 per cent.; peat; mica
207	678–682	Sand: coarse 20 per cent.; medium 40 per cent.; fine 25 per cent.; clay 15 per cent.; peat; mica; trace of gravel
208	682–688	Sand: coarse 20 per cent.; medium 40 per cent.; fine 25 per cent.; clay 15 per cent.; peat; mica; trace of gravel
209	688–692	Fine gravel 5 per cent.; sand: coarse 15 per cent.; medium 50 per cent.; fine 20 per cent.; clay 10 per cent.
210	692–693	Medium sand 30 per cent.; clay 70 per cent.
211	693–694	Clay 60 per cent.; medium sand 35 per cent.; peat 5 per cent.
212	694–695.5	Fine gravel 10 per cent.; sand: coarse 50 per cent.; medium 30 per cent.; clay 10 per cent.
213	695.5–700	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 45 per cent.; clay 10 per cent.
214	700–705	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 45 per cent.; clay 10 per cent.
215	705–708	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 45 per cent.; clay 10 per cent.; with peat
216	708–710	Sand: coarse 20 per cent.; medium 40 per cent.; fine 35 per cent.; clay 5 per cent.

TABLE 15 (*Continued*)

Well 1 (*Concluded*)

Sample	Depth Feet	Character of Material
217	710–713	Sand: coarse 15 per cent.; medium 60 per cent.; fine 25 per cent.; traces of peat; pyrites; fine gravel
218	713–717	Compact mixture of clay, fine gravel; coarse and medium sand; peat
219	717–721	Fine gravel 5 per cent.; sand: coarse 25 per cent.; medium 30 per cent.; fine 30 per cent.; clay 10 per cent.; traces of peat; pyrites
220	721–723.5	Sand: coarse 40 per cent.; medium 60 per cent.
221	723.5–728	Sand: coarse 5 per cent.; medium 80 per cent.; fine 15 per cent.; trace of gravel
222	728–731	Fine gravel 20 per cent.; sand: coarse 60 per cent.; medium 20 per cent.
223	731–733.5	Fine gravel 15 per cent.; sand: coarse 65 per cent.; medium 20 per cent.; traces of clay
224	733.5–734.5	Fine gravel 5 per cent.; sand: coarse 15 per cent.; medium 70 per cent.; clay 10 per cent.
225	734.5–742	Sand: coarse 30 per cent.; medium 60 per cent.; clay 10 per cent ; trace of fine gravel
226	742–747	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 40 per cent.; fine 10 per cent.; peat and clay 5 per cent.
227	747–750	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 40 per cent.; fine 10 per cent.; peat and clay 5 per cent.
228	747–750	Fine gravel 5 per cent.; sand: coarse 40 per cent.; medium 40 per cent.; fine 10 per cent.; peat and clay 5 per cent.
229	750–752	Fine gravel 25 per cent.; sand: coarse 45 per cent.; medium 20 per cent.; fine 10 per cent.
230	750–752	Fine gravel 25 per cent.; sand: coarse 45 per cent.; medium 20 per cent.; fine 10 per cent.
231	752–754	Sand: coarse 20 per cent.; medium 50 per cent.; fine 20 per cent.; clay 10 per cent.; trace of gravel
232	754–757	Fine gravel 10 per cent.; sand: coarse 60 per cent.; medium 25 per cent.; fine 5 per cent.
233	757–758.5	Fine gravel 20 per cent.; sand: coarse 60 per cent.; medium 15 per cent.; gray clay 5 per cent.
234	757–758.5	Fine gravel 20 per cent.; sand: coarse 60 per cent.; medium 15 per cent.; gray clay 5 per cent.
235	758.5–760	Medium sand 30 per cent.; fine 70 per cent.; trace of gravel
236	760–762	Hard gray clay
237a	762–766	Sand: medium 20 per cent.; fine 70 per cent.; clay 10 per cent.
237b	766–768	Hard gray clay
238	768–771	Peat; clay; sand
239	771–773	Clay; fine sand
240	773–775	Sand: coarse 30 per cent.; medium 50 per cent.; fine 15 per cent.; gray clay 5 per cent.
241	773–775	Sand: coarse 30 per cent.; medium 50 per cent.; fine 15 per cent.; gray clay 5 per cent.
242	775–780.5	Clay mixed with gravel and pyrites; peat
243	780.5–786	Gravel: coarse 5 per cent.; fine 50 per cent.; sand: coarse 20 per cent.; medium 20 per cent.; clay 5 per cent.
244	786–787.5	Sand: medium 40 per cent.; fine 55 per cent.; clay 5 per cent.; traces of fine gravel
245	787.5–788	Gravel 25 per cent.; sand 70 per cent.; clay 5 per cent.
247	788–789	" 50 " " " 40 " " " 10 " " pyrites
248	789–790	" 70 " " " 30 " " " pyrites
249	790–791	" 50 " " " 45 " " " 5 per cent.
250	791–798.5	Gravel: coarse 5 per cent.; fine 15 per cent.; sand: coarse 40 per cent.; medium 30 per cent.; fine 10 per cent.; trace of clay
251	798.5–800	Gravel 40 per cent.; sand 60 per cent.; trace of clay
252	800–802	" 45 " " " 50 " " clay 5 per cent.
253	802–808	Fine gravel 10 per cent.; sand: coarse 20 per cent.; medium 40 per cent.; fine 30 per cent.; traces of clay and peat
254	808–809	Gravel 50 per cent.; sand 50 per cent.

TABLE 15 (*Continued*)

CLASSIFICATION OF SAMPLES FROM CALIFORNIA STOVEPIPE WELL 3, EXPERIMENT STATION, WEST ISLIP, LONG ISLAND, 16 INCHES IN DIAMETER. ELEVATION, B. W. S. DATUM: SURFACE OF GROUND, 30; GROUND-WATER, 23.9

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 2	Brown clay 75 per cent.; sand 20 per cent.; gravel 5 per cent.
2	2 – 4	Clay 50 per cent.; gravel: coarse 10 per cent.; fine 5 per cent.; sand: coarse 10 per cent.; medium 10 per cent.; fine 15 per cent.
3	4 – 6	Gravel 15 per cent.; sand 85 per cent.
4	6 – 12	Fine gravel 5 per cent.; sand 95 per cent.
5	12 – 13	Gravel: coarse 50 per cent.; fine 25 per cent.; sand: coarse 15 per cent.; medium 10 per cent.
5a	12 – 13	Sample of largest gravel brought up
6	13 – 15.5	Gravel: coarse 60 per cent.; fine 20 per cent.; sand: coarse 10 per cent.; medium 10 per cent.
7	13 – 15.5	Gravel: coarse 60 per cent.; fine 20 per cent.; sand: coarse 10 per cent.; medium 10 per cent.
8	15.5 – 17	Gravel: coarse 30 per cent.: fine 35 per cent.; sand 35 per cent.
9	15.5 – 17	" " 30 " " " 35 " " " 35 " "
10	17 – 19	" " 55 " " " 30 " " " 15 " "
11	19 – 21	" " 45 " " " 10 " " " 45 " "
12	21 – 23	" " 55 " " " 15 " " " 30 " "
13	23 – 26	" " 30 " " " 10 " " " 60 " "
14	26 – 27	" " 60 " " " 20 " " " 20 " "
15	27 – 29	" " 10 " " " 2 " " " 88 " "
16	29 – 31	Gravel 5 per cent.; sand: coarse 50 per cent.; medium 30 per cent.; fine 15 per cent.
17	31 – 33	Gravel: coarse 35 per cent.; fine 15 per cent.; sand 50 per cent.
18	33 – 35	" " 25 " " " 15 " " " 60 " "
19	35 – 37	Gravel 10 per cent.; sand: coarse 30 per cent.; medium 30 per cent.; fine 30 per cent.
20	37 – 39	Coarse gravel 5 per cent.; sand: coarse 25 per cent.; fine 70 per cent.
21	39 – 41	" " 5 " " " " 15 " " " 80 " "
22	41 – 43	" " 5 " " " " 10 " " " 85 " "
23	43 – 45	" " 2 " " " " 10 " " " 88 " "
24	45 – 49	" " 5 " " " " 10 " " " 85 " "
25	49 – 51	" " 5 " " " " 10 " " " 85 " "
26	51 – 53	" " 2 " " " " 10 " " " 88 " "
27	53 – 55	" " 3 " " " " 10 " " " 87 " "
28	55 – 57	" " 1 " " " " 5 " " " 94 " "
29	57 – 59	Sand: coarse 20 per cent.; medium 40 per cent.; fine 40 per cent.
30	59 – 61	" " 10 " " " 30 " " " 60 " "
31	61 – 63	" " 5 " " " 25 " " " 70 " "
32	63 – 65	" " 5 " " " 25 " " " 70 " " traces of mica
33	65 – 67	Gravel 1 per cent.; sand: coarse 4 per cent.; medium 20 per cent.; fine 75 per cent.; traces of mica
34	67 – 69	Sand: coarse 5 per cent.; medium 15 per cent.; fine 80 per cent.; few small pebbles; traces of mica
35	69 – 71	Sand: coarse 5 per cent.; medium 15 per cent.; fine 80 per cent.; few small pebbles; traces of mica
36	71 – 73	Sand: coarse 5 per cent.; medium 15 per cent.; fine 80 per cent.; few small pebbles; traces of mica
37	73 – 75	Sand: medium 25 per cent.; fine 75 per cent.; traces of mica
38	75 – 77	" " 25 " " " 75 " " " " "
39	77 – 79	" " 25 " " " 75 " " " " "
40	79 – 81	" " 25 " " " 75 " " " " "
41	81 – 83	" " 25 " " " 75 " " " " "
42	83 – 86	Coarse gravel 10 per cent.; sand: medium 20 per cent.; fine 70 per cent.; struck gravel at 85.6 feet
43	86 – 87	Gravel: coarse 35 per cent.; fine 15 per cent.; sand: coarse 10 per cent.; medium 20 per cent.; fine 20 per cent.
44	87 – 89	Gravel: coarse 20 per cent.; fine 55 per cent.; sand 25 per cent.
45	89 – 91	" " 30 " " " 30 " " " 40 " "
46	91 – 93	Gravel: coarse 60 per cent.; fine 20 per cent.; sandstone 10 per cent.; sand 10 per cent.

TABLE 15 (*Continued*)

Well 3 (*Concluded*)

Sample	Depth Feet	Character of Material
47	93 – 95	Gravel: coarse 15 per cent ; fine 5 per cent.; sand 65 per cent.; clay 2 per cent.; sandstone 3 per cent.
48	95 – 97	Fine gray sand 98 per cent.; clay 2 per cent.; mica
49	97 – 99	" " " 98 " " " 2 " " "
50	99–101	Sand: coarse 3 per cent.; medium 20 per cent.; fine 75 per cent.; mica; clay 2 per cent.
51	101–103	Fine gray sand; clay; mica
52	103–105	Fine gray sand 98 per cent.; clay 2 per cent.; mica
53	105–107	Fine gray sand; traces of clay and mica
54a	107–109.5	" " " clay
54b	107–109.5	" " " " lignite
55	109.5–112	Fine sand intermixed with lignite
56	112–113	Fine sand; sandstone; pyrite; lignite
57	113–115	Hard black clay
57a	115–117.5	Fine gray sand mixed with lignite
58	117.5–120	" " " " " "
59	120–122.5	" " " traces of lignite; mica; clay
60	122.5–123	" " " " " " "
61	123–125	" " " " " " "
62	125–127	" " " " " " "
63	127–129	" " " " " " "
64a	129–133	" " " " " " "
64b	131	Pieces of lignite
65	133–135	Fine gray sand; peat; soft sandstone; mica
66	135–138	" " " clay mixed with sand
67	138–141	Hard black clay
68	141–144.5	" " " mixed with lignite and sand
69	144.5–147	Fine gray sand mixed with peat
70	147–148	" " " " " "
71	148–151	Hard black clay
72	151–153	" " "
73	153–155	" " "
74	155–157	" " "
75	157–159	Fine gray sand
76	159–162	" " "
77	162–165	" " " 90 per cent.; clay 10 per cent.
78	165–167	" " " sandstone; clay; lignite
79	167–169	" " " " " "
80	169–171	" " " black clay; sandstone; lignite
81	171–173	" " " " " " "
82	173–175	" " " clay; lignite; mica
83	175–177	" " " lignite; mica
84	177–180	" " " " "
85	180–183	" " " hard black clay at 182 feet
86	183–186	" " " mixed with peat and mica
87	186–190	" " " " " " " "
88	190–192	" " " " " " " "
89	192–194	" " " " " " " "
90	194–196	" " " " " " " "
91	196–198	" " " " " " " "
92	198–200	" " " " " " " "

TABLE 15 (*Continued*)

Classification of Samples from California Stovepipe Well 2, Experiment Station, West Islip, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 30; Ground-water, 23.9

Sample	Depth Feet	Character of Material
1	0 – 3.6	Yellowish brown clay 70 per cent.; sand 20 per cent.; gravel 10 per cent.
2	3.6 – 4.5	Blue clay with traces of sand and gravel
3	4.5 – 6.6	Coarse and fine gravel; coarse sand
4	6.6 – 7	Gravel: fine 50 per cent.; coarse 20 per cent.; coarse sand 30 per cent.
5a	7 – 10	Sand: medium 90 per cent.; coarse 10 per cent.
5b	10 – 12	Coarse and fine gravel
6	12 – 13	Gravel: coarse 85 per cent.; fine 10 per cent.; coarse sand 5 per cent.
7	13 – 16	Sand: medium 60 per cent.; coarse 38 per cent.; gravel 2 per cent.
8	16 – 17	Gravel: coarse 85 per cent.; fine 10 per cent.; coarse sand 5 per cent.
9	17 – 18	" " 20 " " " 75 " " " " 5 " "
10	18 – 19.5	" " 80 " " " 15 " " " " 5 " "
11	19.5 – 21	Coarse sand 40 per cent.; coarse gravel 60 per cent.
12	21 – 23.2	" "
13	23.2 – 25.2	Sand: coarse 20 per cent.; fine 75 per cent.; fine gravel 5 per cent.
14	25.2 – 26.9	" " 60 " " fine gravel 40 per cent.
15	26.9 – 29.2	" medium 75 per cent.; coarse 25 per cent.
16	29.2 – 30	" " 85 " " " 15 " "
17	30 – 33	" " 85 " " " 15 " "
18	33 – 38	" " 85 " " " 15 " "
19	38 – 42	" " 75 " " " 22 " " fine gravel 3 per cent.
20	42 – 46	" " 38 " " fine 60 " " gravel 2 per cent.
21	46 – 48	" " 27 " " " 70 " " " " 3 " "
22	48 – 50	" " 25 " " " 70 " " " " 5 " "
23	50 – 52	" " 30 " " " 50 " " coarse 18 per cent.; fine gravel 2 per cent.
24	52 – 54.5	Medium sand
25	54.5 – 56	Sand: medium 75 per cent.; coarse 25 per cent.
26	56 – 58	Fine sand
27	58 – 62	Sand: fine 75 per cent.; medium 25 per cent.
28	62 – 64	Fine sand
29	64 – 66.5	Sand: fine 85 per cent.; medium 15 per cent.
30	66.5 – 68	" " 85 " " " 15 " "
31	68 – 70	" " 85 " " " 15 " "
32	70 – 72.6	Fine sand
33	72.6 – 74	" "
34	74 – 78.3	" "
35	78.3 – 80	" "
36	80 – 82	Sand: fine 85 per cent.; medium 15 per cent.
37	82 – 84	Fine sand
38	84 – 86	" "
39a	86 – 88	Coarse and fine gravel; pyrite
39b	86 – 88	" " " " "
40	88 – 89.5	Brown sandstone; medium sand cemented by iron
41	89.5 – 91	Sandstone with gravel
42	91 – 92.7	Clay and pyrite
43	92.7 – 93.5	Clay, sandstone and sand
44	93.5 – 95.5	Peat, clay and sand
45	95.5 – 98	Sand: coarse 75 per cent.; medium 25 per cent.
46	98 – 100	" " 50 " " " 50 " "
47	100 – 102	" " 65 " " " 35 " "

TABLE 15 (*Continued*)

WELL 2 (*Concluded*)

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
48	102–104	Coarse and medium sand
49	104–106	" sand
50	106–108	Sand: coarse 65 per cent.; medium 35 per cent.
51	108–111.5	Medium sand, clay and peat
52	111.5–113	" " " " "
53	113–115	" " " " "
54	115–117.5	Coarse and medium sand
55	117.5–119	Medium sand, clay and mica
56	119–121	" "
57	121–128.6	" " and clay
58	128.6–134	" " with mica and organic matter
59	134–136.8	Sand, peat and clay
60	136.8–138	" " " "
61	138–145	Medium sand
62	145–147	" " pyrite; organic matter
63	147–150	" " clay
64	150–154	Clay; medium sand; pyrite
65a	154–158	Black compact clay
65b	154–158	Medium gray sand; pyrite and peat
66	158–162	" sand; trace of clay
67	162–164	" " " " "
68	164–165	" " " " " with peat
69	165–167	" " " " "
70	167–168.5	Coarse and medium sand; trace of clay
71	168.5–170.5	Black clay and fine sand

CLASSIFICATION OF SAMPLES FROM TEST-WELL 565, BAY-SHORE, LONG ISLAND. WELL 101 FEET DEEP, 2 INCHES IN DIAMETER. ELEVATION, B. W. S. DATUM: SURFACE OF GROUND, 30; BOTTOM, —71

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 6	Fine gravel 20 per cent.; white sand: coarse 40 per cent.; fine 40 per cent.; trace of loam
2	6 – 12	Fine gravel 70 per cent.; white sand: coarse 20 per cent.; fine 10 per cent.
3	12 – 18	Fine gravel 70 per cent.; white sand: coarse 20 per cent.; fine 10 per cent.
4	18 – 24	Fine gravel 20 per cent.; white sand: coarse 20 per cent.; medium 40 per cent.; fine 20 per cent.
5	24 – 30	Fine gravel 20 per cent.; white sand: coarse 20 per cent.; medium 40 per cent.; fine 20 per cent.
6	30 – 36	White sand: coarse 60 per cent.; medium 20 per cent.; fine 20 per cent.
7	36 – 42	White sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
8	42 – 48	Fine gravel 10 per cent.; white sand: coarse 20 per cent.; medium 50 per cent.; fine 20 per cent.
9	48 – 54	White sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
10	54 – 60	White sand: medium 30 per cent.; fine 40 per cent.; superfine 30 per cent.
11	60 – 65	Yellow sand: fine 70 per cent.; superfine 30 per cent.
12	65 – 70	" " " 70 " " " 30 " "
13	70 – 75	White " " 40 " " " 60 " "
14	75 – 79	Fine gravel 10 per cent.; white sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
15	79 – 84	Light gray sand: medium 50 per cent.; fine 50 per cent.; trace of peat
16	84 – 88	Light gray sand: medium 50 per cent.; fine 50 per cent.; trace of peat
17	88 – 93	Light gray sand: medium 50 per cent.; fine 50 per cent.; trace of peat
18	93 – 97	Light gray sand: coarse 30 per cent.; medium 50 per cent.; fine 20 per cent.; trace of peat
19	97 – 100	Light gray sand: coarse 30 per cent.; medium 50 per cent.; fine 20 per cent; trace of peat

TABLE 15 (*Continued*)

Classification of Samples from California Stovepipe Well 6, Corner Grand Boulevard and 44th Street, North of Islip, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 37.6; Groundwater, 24.8

Sample	Depth Feet	Character of Material
1	0 – 3	Sandy loam
2	3 – 5	Sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
3	5 – 7	Gravel: coarse 10 per cent.; fine 10 per cent.; pale yellow sand: coarse 60 per cent.; medium 20 per cent.
4	7 – 10	Gravel: coarse 20 per cent.; fine 10 per cent.; pale yellow sand: coarse 50 per cent.; medium 20 per cent.
5	10 – 14	Gravel: coarse 10 per cent.; fine 10 per cent.; pale yellow sand: coarse 20 per cent.; medium 40 per cent.; fine 20 per cent.
6	14 – 17	Gravel: coarse 30 per cent.; fine 20 per cent.; sand: coarse 40 per cent.; medium 10 per cent.
7	17 – 20	Gravel: coarse 20 per cent.; fine 10 per cent.; sand: coarse 30 per cent.; medium 40 per cent.
8	20 – 23	Gravel: coarse 20 per cent.; fine 20 per cent.; sand: coarse 20 per cent.; medium 40 per cent.
9	23 – 24	Gravel: coarse 10 per cent.; fine 10 per cent.; yellow sand: coarse 20 per cent.; medium 60 per cent.
10	24 – 26	Gravel: coarse 5 per cent.; fine 5 per cent.; yellow sand: coarse 15 per cent.; medium 50 per cent.; fine 25 per cent.
11	26 – 28	Gravel: coarse 5 per cent.; fine 5 per cent.; yellow sand: coarse 20 per cent.; medium 50 per cent.; fine 20 per cent.
12	28 – 30	Gravel: coarse 10 per cent.; fine 10 per cent.; sand: coarse 20 per cent.; medium 40 per cent.; fine 20 per cent.
13	30 – 32	Sand: coarse 15 per cent.; medium 50 per cent.; fine 35 per cent.
14	32 – 34	Gravel: coarse 5 per cent.; fine 10 per cent.; sand: coarse 20 per cent.; medium 40 per cent.; fine 25 per cent.
15	34 – 36	Fine gravel 10 per cent.; sand: coarse 30 per cent.; medium 40 per cent.; fine 20 per cent.
16	36 – 38	Gravel 5 per cent.; sand: coarse 5 per cent.; medium 60 per cent.; fine 30 per cent.
17	38 – 40	Gravel 5 per cent.; sand: coarse 5 per cent.; medium 60 per cent.; fine 30 per cent.
18	40 – 42	Gravel 5 per cent.; sand: coarse 5 per cent.; medium 60 per cent.; fine 30 per cent.
19	42 – 44	Gravel: coarse 5 per cent.; fine 5 per cent.; sand: coarse 20 per cent.; medium 40 per cent.; fine 30 per cent.
20	44 – 46	Gravel 1 per cent.; sand: coarse 10 per cent.; medium 70 per cent.; fine 19 per cent.
21	46 – 48	Gravel 1 per cent.; sand: coarse 10 per cent.; medium 70 per cent.; fine 19 per cent.
22	48 – 50	Gravel: coarse 10 per cent.; fine 10 per cent.; rich yellow sand: coarse 30 per cent.; medium 50 per cent.
23	50 – 52	Gravel: coarse 10 per cent.; fine 10 per cent.; rich yellow sand: coarse 30 per cent.; medium 50 per cent.
24	52 – 54	Gravel: coarse 5 per cent.; fine 5 per cent.; yellow sand: coarse 10 per cent.; medium 40 per cent.; fine 40 per cent.
25	54 – 56	Dark yellow gravel 5 per cent.; sand: coarse 15 per cent.; medium 50 per cent.; fine 30 per cent.
26	56 – 58	Dark yellow sand 0; sand: coarse 5 per cent.; fine 45 per cent.; medium 50 per cent.
27	58 – 60	Dark brown sand: medium 60 per cent.; fine 40 per cent.
28	60 – 62	Light brown sand: coarse 10 per cent.; fine 40 per cent.; medium 50 per cent.
29	62 – 64	Dark brown sand: medium 60 per cent.; fine 40 per cent.
30	64 – 68	" " " coarse 5 per cent.; fine 30 per cent.; medium 65 per cent.
31	68 – 70	Dark brown sand: coarse 0; fine 50 per cent.; medium 50 per cent.
32	70 – 72	" " " medium 50 per cent.; fine 50 per cent.
33	72 – 74	" yellow " " 50 " " " 50 " "
34	74 – 76	" " " " 50 " " " 50 " "
35	76 – 78	" " " " 50 " " " 50 " "
36	78 – 80	" " " " 50 " " " 50 " "
37	80 – 82	" " " " 50 " " " 50 " "
38	82 – 84	" " " " 50 " " " 50 " "
39	84 – 86	" " " " 50 " " " 50 " "
40	86 – 88	" " " coarse 20 per cent.; medium 50 per cent.; fine 30 per cent.

TABLE 15 (*Continued*)

Well 6 (*Continued*)

Sample	Depth Feet	Character of Material
41	88 – 90	Dark yellow sand: medium 40 per cent.; fine 60 per cent.
42	90 – 92	" " " : coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
43	92 – 94	Dark yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.
44	94 – 96	Dark yellow sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
45	96 – 98	Dark yellow sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
46	98–100	Dark yellow sand: coarse 5 per cent.; medium 45 per cent.; fine 50 per cent.
47	100–102	Dark yellow sand: medium 50 per cent.; fine 50 per cent.
48	102–104	" " " " 40 " " " 60 " "
49	104–106	Dark brown sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.
50	106–108	Dark brown sand: medium 60 per cent.; fine 40 per cent.
51	108–109	Coarse gravel 5 per cent.; sand: medium 60 per cent.; fine 35 per cent.
52	109–112	Gray and brown clay; sandstone and pyrite
53	112–114	Soft gray clay
54	114–116	Gravel: coarse 10 per cent.; fine 5 per cent.; sand: coarse 30 per cent.; medium 30 per cent.; fine 25 per cent.
55	116–118	Fine gravel 1 per cent.; sand: coarse 5 per cent.; medium 60 per cent.; fine 34 per cent.
56	118–122	Medium yellow sand
57	122–124	White and brown clay stratified 40 per cent.; fine yellow sand 60 per cent.
58	124–126	Fine and superfine sand; brown clay 30 per cent.; sandstone 10 per cent.
59	126–128	Gray and red clay stratified
60	128–130	Fine and superfine sand 80 per cent.; brown clay 20 per cent.
61	130–134	Fine orange yellow sand 2 per cent.
62	134–140	" " " " 2 " "
63	140–146	Orange yellow sand; fine nodules iron cemented
64	146–151	" " " " " " "
65	151–156	Yellow sand: medium 50 per cent.; fine 50 per cent.
66	156–160	White clay, plastic
67	160–163	Yellow sand: medium 60 per cent.; fine 40 per cent.
68	163–167	Dark sand: medium 60 per cent.; fine 40 per cent.
69	167–169	Fine white sand; peat and sandstone
70	169–171	White plastic clay; nodules of sand cemented with iron
71	171–173	White plastic clay; white and pale yellow sand, fine and superfine below
72	173–175	White sand: medium 70 per cent.; fine 30 per cent.
73	175–177	" " coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.; micaceous
74	177–179	Yellow sand: coarse 60 per cent.; medium 40 per cent.; nodules of iron
75	179–183	Hard gray clay
76	183–189	White and pale yellow sand: medium 60 per cent.; fine 40 per cent.; nodules of iron
77	189–195	White and pale yellow sand: medium 60 per cent.; fine 40 per cent.; nodules of iron
78	195–201	White and pale yellow sand: coarse 50 per cent.; medium 50 per cent.
79	201–204.5	Blue and brown clay stratified with peat
80	204.5–211	White and yellow sand: medium 60 per cent.; fine 40 per cent.
81	211–216	Pale yellow and white sand: medium 60 per cent.; fine 40 per cent.
82	216–219	Stratified yellow clay and peat
83	219–225	Pale yellow sand: medium 60 per cent.; fine 40 per cent.; nodules of iron rust
84	225–231	Pale gray sand: fine 60 per cent.; superfine 40 per cent.
85	231–233	Peat and fine white sand intermixed
86	233–239	Pale yellow sand: medium 60 per cent.; fine 40 per cent.; iron rust
87	239–245	" " " " 60 " " " 40 " " nodules of iron rust
88	245–251	Pale yellow sand: medium 60 per cent.; fine 40 per cent.
89	251–257	" " " (iron rust): fine 80 per cent.; yellow clay 20 per cent.
90	257–261	Blue-black clay and peat
91	261–267	Pale yellow sand: coarse 50 per cent.; medium 30 per cent.; clay 20 per cent.

TABLE 15 (*Continued*)

Well 6 (*Concluded*)

Sample	Depth Feet	Character of Material
92	267–271	Pale yellow sand: medium 80 per cent.; stratified yellow clay 20 per cent.
93	271–277	Pale yellow sand: coarse 60 per cent.; medium 40 per cent.
94	277–283	" " " 80 per cent.; yellow clay 20 per cent.
95	283–290	" " " medium 70 per cent.; fine 30 per cent.
96	290–295	" " " " 70 " " " 30 " "
97	295–301	" " " " 70 " " " 30 " "
98	301–307	" " " " 70 " " " 30 " "
99	307–313	" " " " 70 " " " 30 " "
100	313–320	Pale gray and yellow sand: medium 60 per cent.; fine 40 per cent.; nodules of iron cemented with sand
101	320–326	Pale yellow sand: medium 70 per cent.; fine 30 per cent.
102	326–331	Pale gray and yellow sand: medium 60 per cent.; fine 40 per cent.; nodules of iron cemented with sand
103	331–337	Pale gray sand: fine 60 per cent.: superfine 40 per cent.; trace of blue clay
104	337–343	Pale gray sand: fine 60 per cent.; superfine 40 per cent.; trace of blue clay
105	343–346	Pale gray sand: medium 80 per cent.; fine 20 per cent.
106	346–347.5	Pyrites
107	347.5–351	Lignite
108	351–353	Hard black clay
109	353–355	" " "
110	355–357	" " " pyrite
111	357–363	" " " "
112	363–367	" " " "
113	367–372	" " "
114	372–378	Sharp pale gray sand: coarse 30 per cent.; medium 70 per cent.
115	378–384	" " " " " 30 " " " 70 " "
116	384–390	Dark gray sand: fine 50 per cent.; superfine 50 per cent.
117	390–396	" " " " 50 " " " 50 " "
118	396–400	" " " " 50 " " " 50 " "
119	400–406	" " " medium 50 per cent.; fine 40 per cent.; blue clay 10 per cent.; trace of peat
120	406–409	Dark gray sand: medium 50 per cent.; fine 40 per cent.; blue clay 10 per cent.; trace of peat
121	409–414	Hard gray clay; pyrites
122	414–418	" black "
123	418–424	Dark gray sand: fine 50 per cent.; superfine 40 per cent.; blue clay 10 per cent.; trace of peat
124	424–430	Dark gray sand: fine 50 per cent.; superfine 40 per cent.; blue clay 10 per cent.; trace of peat
125	430–436	Dark gray superfine sand; trace of peat
126	436–443	Pale gray medium sand; iron pyrites
127	443–445	Hard gray clay
128	445–450	" " "
129	450–454	" " "
130	454–457	" black "
131	457–463	" " "
132	463–468	Superfine gray sand; clay

TABLE 15 (*Continued*)

CLASSIFICATION OF SAMPLES FROM TEST-WELL 571, EAST ISLIP, LONG ISLAND. WELL 117 FEET IN DEPTH, 2 INCHES IN DIAMETER. ELEVATION, B. W. S. DATUM: SURFACE OF GROUND, 32; BOTTOM, —85

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 7	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; medium 20 per cent.
2	7 – 13	Fine gravel 10 per cent.; yellow sand: coarse 50 per cent.; medium 40 per cent.
3	13 – 19	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; medium 20 per cent.
4	19 – 26	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
5	26 – 32	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
6	32 – 39	Yellow sand: coarse 60 per cent.; medium 40 per cent.
7	39 – 46	" " " 40 " " " 60 " "
8	46 – 52	" " " 20 " " " 60 " " fine 20 per cent.
9	52 – 57	Yellow sand: medium 60 per cent.; fine 40 per cent.
10	57 – 62	" " " 40 " " " 40 " " superfine 20 per cent.
11	62 – 66	Yellow sand: medium 40 per cent.; fine 40 per cent.; superfine 20 per cent.
12	66 – 71	Yellow sand: medium 40 per cent.; fine 40 per cent.; superfine 20 per cent.
13	71 – 76	Yellow sand: medium 40 per cent.; fine 40 per cent.; superfine 20 per cent.; trace of peat
14	76 – 80	Yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.
15	80 – 85	Yellow sand: medium 20 per cent.; fine 60 per cent.; superfine 20 per cent.
16	85 – 89	Yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.; trace of peat
17	89 – 95	Yellow sand: medium 60 per cent.; fine 40 per cent.
18	95 – 102	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; medium 20 per cent.
19	102 – 105	Blue clay 90 per cent.; coarse sand 10 per cent.
20	105 – 108	" "
21	108 – 109	" "
22	109 – 111	" " 90 per cent.; fine sand 10 per cent.
23	111 – 113	" " trace of sand
24	113 – 117	Coarse gravel 70 per cent.; fine sand 30 per cent.

TABLE 15 (*Continued*)

Classification of Samples from Test-well 465, Sayville, Long Island. Well 121 Feet in Depth, 2 Inches in Diameter

Sample	Depth Feet	Character of Material
1	0 – 7	Fine gravel 50 per cent.; coarse sand 40 per cent.; loam 10 per cent.
2	7 – 13	" " 40 " " " " 40 " " fine sand 20 per cent.
3	13 – 19	White sand: medium 60 per cent.; coarse 30 per cent.; gravel 10 per cent.
4	19 – 26	White sand: medium 60 per cent.; coarse 30 per cent.; gravel 10 per cent.
5	26 – 33	White sand: medium 80 per cent.; coarse 15 per cent.; gravel 5 per cent.
6	33 – 39	White sand: medium 90 per cent.; coarse 10 per cent.
7	39 – 45	" " " 60 " " " 40 " "
8	45 – 52	" " " 60 " " " 40 " "
9	52 – 59	" " fine 60 per cent.; medium 40 per cent.
10	59 – 65	" " " 60 " " " 40 " "
11	65 – 73	" " " 60 " " " 40 " "
12	73 – 80	" " medium 60 per cent.; fine 40 per cent.
13	80 – 86	" " " 60 " " " 40 " "
14	86 – 93	" " " 60 " " " 40 " "
15	93–100	" " " 70 " " " 30 " "
16	100–107	" " " 70 " " " 30 " "
17	107–114	Gray sand: superfine 60 per cent.; fine 40 per cent.
18	114–121	" " " 80 " " " 20 " "

Classification of Samples from Test-well 478, Bayport, Long Island. Well 118 Feet in Depth, 2 Inches in Diameter

Sample	Depth Feet	Character of Material
1	0 – 6	Fine gravel 30 per cent.; white coarse sand 60 per cent.; loam 10 per cent.
2	6 – 13	Fine gravel 30 per cent.; white coarse sand 70 per cent.; trace of loam
3	13 – 20	Fine gravel 30 per cent.; white coarse sand 70 per cent.
4	20 – 27	" " 10 " " white sand: coarse 60 per cent.; medium 30 per cent.
5	27 – 34	Fine gravel 10 per cent.; white sand: coarse 60 per cent.; medium 30 per cent.
6	34 – 40	White sand: coarse 60 per cent.; medium 40 per cent.
7	40 – 47	" " " 60 " " " 40 " "
8	47 – 53	" " " 60 " " " 40 " "
9	53 – 60	" " " 60 " " " 40 " "
10	60 – 66	" " medium 40 per cent.; fine 60 per cent.
11	66 – 73	Brown sand: coarse 20 per cent.; medium 40 per cent.; fine 40 per cent.
12	73 – 80	Brown sand: coarse 40 per cent.; medium 40 per cent.; fine 20 per cent.
13	80 – 86	Brown sand: coarse 20 per cent.; medium 40 per cent.; fine 40 per cent.
14	86 – 93	Brown sand: medium 60 per cent.; fine 40 per cent.
15	93 – 99	" " " 60 " " " 40 " "
16	99 – 106	Brown sand: medium 20 per cent.; fine 60 per cent.; superfine 20 per cent.
17	106 – 113	Brown sand: medium 20 per cent.; fine 60 per cent.; superfine 20 per cent.
18	113 – 118	Brown sand: fine 80 per cent.; superfine 20 per cent.

TABLE 15 (*Continued*)

Classification of Samples from California Stovepipe Well 7, North of Patchogue, and Easterly Side of Patchogue Lake, Long Island, 12 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 25.7; Ground-water, 18.2

Sample	Depth Feet	Character of Material
1	0 – 1.5	Light brown sandy loam
2	1.5 – 5	" " " "
3	5 – 8	Pale yellow sand: medium 60 per cent.; fine 40 per cent.
4	8 – 11	" " coarse gravel 5 per cent.; sand 55 per cent.; fine 40 per cent.
5	11 – 15	Gravel: coarse 10 per cent.; fine 5 per cent.; sand: coarse 40 per cent.; medium 45 per cent.
6	15 – 19	Pale gravel: coarse, 25 per cent.; fine 10 per cent.; sand: coarse 30 per cent.; medium 35 per cent.
7	19 – 23	Gravel: coarse 15 per cent.; fine 5 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; pale
8	23 – 27	Gravel 5 per cent.; sand: coarse 40 per cent.; medium 55 per cent.; pale
9	27 – 32	Gravel 5 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; fine 15 per cent.; pale
10	32 – 35	Pale gravel: coarse 25 per cent.; fine 10 per cent.; sand: coarse 20 per cent.; medium 35 per cent.; fine 10 per cent.
11	35 – 40	Pale coarse gravel 2 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; fine 18 per cent.
12	40 – 44	Brownish yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.
13	44 – 47	Brownish yellow coarse gravel 5 per cent.; sand: coarse 10 per cent.; medium 50 per cent.; fine 35 per cent.
14	47 – 51	Brownish yellow sand: coarse 30 per cent.; medium 50 per cent.; fine 20 per cent.
15	51 – 55	Brownish yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 25 per cent.; gravel 5 per cent.
16	55 – 59	Brownish yellow sand: coarse 40 per cent.; medium 40 per cent.; fine 15 per cent.; gravel 5 per cent.
17	59 – 63	Brownish yellow gravel 5 per cent.; sand: coarse 30 per cent.; medium 40 per cent.; fine 25 per cent.
18	63 – 67	Brownish yellow gravel 1 per cent.; sand: coarse 10 per cent.; medium 60 per cent.; fine 29 per cent.
19	67 – 71	Brownish yellow gravel 5 per cent.; sand: coarse 10 per cent.; medium 50 per cent.; fine 35 per cent.
20	71 – 75	Brownish yellow gravel 5 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; fine 15 per cent.
21	75 – 79	Brownish yellow gravel 5 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; fine 15 per cent.
22	79 – 83	Brownish yellow gravel 5 per cent.; sand: coarse 40 per cent.; medium 50 per cent.; fine 5 per cent.
23	83 – 87	Brownish yellow gravel 1 per cent.; sand: coarse 4 per cent.: medium 50 per cent.; fine 45 per cent.
24	87 – 91	Fine light brown sand; mica flakes
25	91 – 95	" " " " " "
26	95 – 99	" pale yellow sand; mica flakes
27	99 – 103	" " " " " "
28	103 – 107	" and medium yellow sand; mica flakes
29	107 – 111	" " " rich yellow sand
30	111 – 117	" " " " " "
31	117 – 121	" " " " " " mica; traces of brown clay
32	121 – 125	" " superfine " " " " " " " "
33	125 – 129	Dark yellow fine sand; mica flakes
34	129 – 133	" " " " " "
35	133 – 137	Gravel: coarse 2 per cent.; fine 3 per cent.; sand: coarse 5 per cent.; medium 60 per cent.; fine 30 per cent.
36	137 – 141	Fine gravel 5 per cent.; sand: coarse 60 per cent.; medium 35 per cent.
37	141 – 145	Coarse gravel 5 per cent.; sand: coarse 75 per cent.; medium 20 per cent.
38	145 – 149	Fine gravel 5 per cent.; sand: coarse 75 per cent.; medium 20 per cent.
39	149 – 153	Coarse gravel 10 per cent.; sand: coarse 70 per cent.; medium 20 per cent.

TABLE 15 (*Continued*)

Well 7 (*Concluded*)

Sample	Depth Feet	Character of Material
40	153–157	Yellow gravel: coarse 25 per cent.; fine 10 per cent.; sand: coarse 35 per cent.; medium 20 per cent.; pyrites 10 per cent.
41	157–161	Hard black and brown clay stratified
42	161–167	Sand: coarse 5 per cent.; medium 55 per cent.; fine 40 per cent.; dark brown
43	167–170	Hard black clay
44	170–174	Dark yellow sand: coarse 20 per cent.; medium 40 per cent.; fine 40 per cent.; pyrites
45	174–176	Pale yellow medium sand 75 per cent.; blue clay 15 per cent.; pyrites 10 per cent.
46	176–178	Hard black clay
47	178–182	Medium and fine gray sand; mica flakes
48	182–185	" " " " " " "
49	185–191	Fine gray sand; mica flakes; peat
50	191–197	" " " " " "
51	197–203	" " " " " "
52	203–209	" " " " " "
53	209–215	" and superfine gray sand
54	215–218	" " " " "
55	218–221	Hard brownish black clay; lignite
56	221–225	Fine gray sand; mica flakes; peat
57	225–230	" and medium gray sand
58	230–231	Soft blue-black clay; pyrites
59	231–235	Fine gray sand; mica flakes
60	235–238	Hard " clay
61	238–243	" black " pyrites
62	243–247	" blue-gray clay; pyrites
63	247–248	" " " " "
64	248–256	" gray clay
65	248–256	" " "
66	256–259	" brownish black clay
67	259–263	Fine gray sand; mica; traces of clay
68	263–267	" " " " " " "
69	267–271	" " " " " " "
70	271–275	" " " " " " " peat
71	275–278	Fine gray sand; mica; traces of clay; peat
72	278–284	" " " " " " " "
73	284–290	" " " " " " " "
74	290–296	" " " " " " " "
75	296–302	" " " " " " " "
76	302–307	" " " " " " " "
77	307–309	Soft blue-gray clay; pyrites
78	309–315	Fine gray sand; traces of clay; mica; peat
79	315–321	" " " " " " " pyrites
80	321–327	" " " " " " " "
81	327–333	" " " " " " " "
82	333–339	" " " " " " " "
83	339–344	" " " gray clay and peat intermixed
84	344–347	Soft black clay; peat
85	347–353	Fine gray sand; mica; peat
86	353–359	" " " " "
87	359–360	Soft gray clay; peat; pyrites
88	360–365	Fine gray sand; peat; mica
89	365–371	" " " " "
90	371–377	" " " " "
91	377–383	" " " " "
92	383–389	" " " " " gray clay
93	389–395	" " " " "
94	395–401	" " " " " gray clay
95	401–407	" " " " "
96	407–413	" " " " " traces of clay
97	413–419	" " " mica
98	419–425	" " " " peat
99	425–430	" " " "
100	430–436	" " " " peat
101	436–441	" " " " 50 per cent.; soft gray clay 50 per cent.
102	441–442.5	Hard black clay
103	442.5–444	Soft light gray clay
104	444–445	" black clay mixed with peat; pyrites
105	445–451	Fine gray sand 75 per cent.; soft black clay 25 per cent.
106	451–457	" " " 90 " " " " " 10 " "
107	457–463	" " " 80 " " " " " 10 " " pyrites 10 per cent.

TABLE 15 (*Continued*)

CLASSIFICATION OF SAMPLES FROM TEST-WELL 182, EAST PATCHOGUE, LONG ISLAND. WELL 99 FEET IN DEPTH, 2 INCHES IN DIAMETER. ELEVATION, B. W. S. DATUM: SURFACE OF GROUND, 27

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 0.5	Medium yellow sandy loam
2	0.5 – 4	Yellow sand: coarse 40 per cent.; medium 60 per cent.
3	4 – 10	Fine gravel 20 per cent.; yellow sand: coarse 60 per cent.; medium 20 per cent.
4	10 – 17	Fine gravel 20 per cent.; yellow sand: coarse 20 per cent.; medium 60 per cent.
5	17 – 23	Fine gravel 20 per cent.; yellow sand: coarse 20 per cent ; medium 60 per cent.
6	23 – 30	Yellow sand: medium 40 per cent.; fine 60 per cent.
7	30 – 35	" " " 40 " " " 60 " "
8	35 – 42	" " " 80 " " " 20 " "
9	42 – 49	Brown " " 60 " " " 40 " "
10	49 – 55	" " " 60 " " " 40 " "
11	55 – 58	Fine gravel 20 per cent.; brown sand: coarse 60 per cent.; medium 20 per cent.
12	58 – 65	Fine gravel 20 per cent.; brown sand: coarse 60 per cent.; medium 20 per cent.
13	65 – 71	Fine gravel 20 per cent.; brown sand: coarse 60 per cent.; medium 20 per cent.
14	71 – 75	Yellow sand: coarse 40 per cent.; medium 40 per cent.; fine 20 per cent.
15	75 – 81	Yellow fine sand 100 per cent.
16	81 – 88	" " " 100 " "
17	88 – 94	" " " 100 " "
18	94 – 99	White medium sand 100 per cent.

TABLE 15 (*Continued*)

CLASSIFICATION OF SAMPLES FROM CALIFORNIA STOVEPIPE WELL 8, AT ROAD INTERSECTIONS ONE MILE NORTH OF BROOKHAVEN RAILROAD STATION, LONG ISLAND, 12 INCHES IN DIAMETER. ELEVATION, B. W. S. DATUM: SURFACE OF GROUND, 35.5; GROUND-WATER, 22.7

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 2	Light brown gravelly loam
2	2 – 3	Light yellow clay 90 per cent.; fine gravel 10 per cent.
3	3 – 4	Gravel: coarse 50 per cent.; fine 30 per cent.; dark yellow sand 20 per cent.
4	4 – 8	White and light yellow gravel: coarse 20 per cent.; fine 5 per cent.; sand: coarse 10 per cent.; medium 55 per cent.; fine 10 per cent.
5	8 – 12	White and light yellow gravel: coarse 3 per cent.; fine 4 per cent.; sand: coarse 50 per cent.; medium 38 per cent.; fine 5 per cent.
6	12 – 15	White and light yellow gravel: coarse 30 per cent.; sand: coarse 35 per cent.; medium 25 per cent.; fine 10 per cent.
7	15 – 18	White and light yellow gravel: coarse 5 per cent.; fine 5 per cent.; sand: coarse 40 per cent.; medium 35 per cent.; fine 15 per cent.
8	18 – 22	White and light yellow gravel: coarse 20 per cent.; fine 10 per cent.; sand: coarse 35 per cent.; medium 30 per cent.; fine 5 per cent.
9	22 – 26	White and light yellow gravel: coarse 55 per cent.; fine 10 per cent.; sand: coarse 20 per cent.; medium 15 per cent.
10	26 – 30	White and light yellow gravel 10 per cent.; sand: coarse 30 per cent.; medium 45 per cent.; fine 15 per cent.
11	30 – 34	White and light yellow coarse gravel 55 per cent.; sand: coarse 15 per cent.; medium 25 per cent.; fine 5 per cent.
12	34 – 38	White and light yellow gravel: coarse 70 per cent.; fine 10 per cent.; sand: coarse 10 per cent.; medium 10 per cent.
13	38 – 42	White and light yellow gravel 5 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; fine 15 per cent.
14	42 – 46	White and light yellow gravel: coarse 50 per cent.; fine 5 per cent.; sand: coarse 20 per cent.; medium 20 per cent.; fine 5 per cent.
15	46 – 50	White and light gravel 10 per cent.; sand: coarse 30 per cent.; medium 50 per cent.; fine 10 per cent.
16	50 – 54	White and light yellow gravel 10 per cent.; sand: coarse 40 per cent.; medium 40 per cent.; fine 10 per cent.
17	54 – 58	White and light yellow gravel: coarse 15 per cent.; fine 10 per cent ; sand: coarse 35 per cent.; medium 30 per cent.; fine 10 per cent.
18	58 – 62	White and light yellow gravel: coarse 5 per cent.; fine 10 per cent.; sand: coarse 45 per cent.; medium 30 per cent.; fine 10 per cent.
19	62 – 66	White and light yellow coarse gravel 10 per cent.; sand: coarse 25 per cent.; medium 45 per cent.; fine 20 per cent.
20	66 – 70	White and light yellow coarse gravel 2 per cent.; sand: coarse 13 per cent.; medium 50 per cent.; fine 35 per cent.
21	70 – 74	White and light yellow coarse gravel 10 per cent.; sand: coarse 20 per cent.; medium 45 per cent.; fine 25 per cent.
22	74 – 76	White and light yellow sand: coarse 20 per cent.; medium 50 per cent.; fine 30 per cent.
23	76 – 80	White and light yellow coarse gravel 5 per cent.; sand: coarse 15 per cent.; medium 50 per cent.; fine 30 per cent.
24	80 – 84	White and light yellow sand: coarse 20 per cent.; medium 45 per cent.; fine 35 per cent.
25	84 – 88	White and light yellow coarse gravel 5 per cent.; sand: coarse 10 per cent.; medium 40 per cent.; fine 45 per cent.
26	88 – 91	White and light yellow sand: coarse 20 per cent.; medium 50 per cent.; fine 30 per cent.
27	91 – 95	White and light yellow coarse gravel 5 per cent.; sand: coarse 15 per cent.; medium 50 per cent ; fine 30 per cent.
28	95 – 99	White and light yellow sand: coarse 10 per cent.; medium 60 per cent.; fine 30 per cent.
29	99 – 103	White and light yellow sand: coarse 10 per cent.; medium 50 per cent.; fine 40 per cent.
30	103 – 105	White and light yellow fine gravel 2 per cent.; sand: coarse 10 per cent.; medium 45 per cent.; fine 43 per cent.
31	105 – 109	White and light yellow gravel: coarse 50 per cent.; fine 5 per cent.; sand: coarse 15 per cent.; medium 20 per cent.; fine 10 per cent.

TABLE 15 (*Continued*)

WELL 8 (*Continued*)

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
32	109–113	White and light yellow gravel: coarse 15 per cent.; fine 5 per cent.; sand: coarse 15 per cent.; medium 45 per cent.; fine 20 per cent.
33	113–117	White and light yellow gravel: coarse 5 per cent.; fine 5 per cent.; sand: coarse 15 per cent.; medium 45 per cent.; fine 30 per cent.
34	117–121	White and light yellow gravel 5 per cent.; sand: coarse 10 per cent.; medium 30 per cent.; fine 55 per cent.
35	121–125	White and light yellow sand: coarse 5 per cent.; medium 25 per cent.; fine 70 per cent.
36	125–128	White and light yellow sand: coarse 5 per cent.; medium 10 per cent.; fine 85 per cent.
37	128–132	Light brown sand: fine 65 per cent.; superfine 35 per cent.
38	132–136	" " sand: medium 10 per cent.; fine 70 per cent.; superfine 20 per cent.
39	136–138	Light brown sand: medium 10 per cent.; fine 75 per cent.; superfine 15 per cent.
40	138–142	White and light yellow sand: coarse 25 per cent.; medium 50 per cent.; fine 25 per cent.
41	142–146	White and light yellow sand: coarse 30 per cent.; medium 50 per cent.; fine 20 per cent.
42	146–150	White and light yellow gravel: coarse 5 per cent.; fine 5 per cent.; sand: coarse 35 per cent.; medium 50 per cent.; fine 5 per cent.
43	150–155	White and light yellow gravel: coarse 35 per cent.; fine 10 per cent.; sand: coarse 20 per cent.; medium 20 per cent.; fine 15 per cent.
44	155–158	White and light yellow gravel: coarse 75 per cent.; fine 10 per cent.; sand: coarse 10 per cent.; medium 5 per cent.
45	158–162	Yellow green clay mixed with sand and gravel compacted, heaty odor
46	162–166	" " gravel: coarse 25 per cent.; fine 10 per cent.; sand: coarse 35 per cent.; medium 20 per cent.; fine 10 per cent.
47	166–170	White and light yellow gravel: coarse 60 per cent.; fine 20 per cent.; sand: coarse 10 per cent.; medium 10 per cent.
48	170–173	White and light yellow gravel: coarse 40 per cent.; fine 20 per cent.; sand: coarse 20 per cent.; medium 20 per cent.
49	173–177	Gray fine sand; mica flakes; traces of clay
50	177–181	" " " " " " " "
51	181–185	" " and medium sand; sandstone; traces of clay
52	185–189	Light gray gravel 5 per cent.; sand: medium 60 per cent.; fine 35 per cent.
53	189–193	Light gray medium and fine sand
54	193–197	" " " " " "
55	197–202	" " " " " "
56	202–204	Black peat mixed with soft black clay
57	204–206	Dark gray medium and fine sand; peat
58	206–211	Steel gray hard clay
59	211–215	Gray medium and fine sand; mica flakes; nearly white when dry
60	215–219	" " " " " " " " " " "
61	219–223	" " " " " " " " " " "
62	223–228	" " " " " " " " " " "
63	228–232	" " " " " " " " " " "
64	232–236	" " " " " " " " " " "
65	236–240	" " " " " " "
66	240–245	" " " " " " "
67	245–250	" " " " " " "
68	250–253	" gravel 5 per cent.; medium and fine sand; sandstone; peat
69	253–257	" sand: coarse 10 per cent.; medium 70 per cent.; fine 20 per cent.
70	257–261	" " " 10 " " " 70 " " " 20 " "
71	261–265	" " " 10 " " " 70 " " " 20 " "
72	265–269	" " " 10 " " " 70 " " " 20 " "
73	269–274	" " " 10 " " " 70 " " " 20 " "
74	274–276	" " " 10 " " " 70 " " " 20 " "
75	276–280	Black hard clay
76	280–289	" " "
77	289–293	Gray fine and medium sand
78	293–298	" " " " "
79	298–304	" " " " "
80	304–308	" " " " "
81	308–312	" " " "
82	312–316	Black hard clay
83	316–322	" " "

TABLE 15 (*Continued*)

WELL 8 (*Continued*)

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
84	322–328	Gray medium and fine sand
85	328–334	Fine gray micaceous sand
86	334–337	" " " "
87	337–338	Bluish gray hard clay
88	338–340	" " " " peat
89	340–343	Fine gray micaceous sand
90	343–349	" " " "
91	349–355	Medium gray sand; pyrites; peat
92	355–361	Fine and medium gray sand; peat
93	361–367	" gray micaceous sand
94	367–373	" " " "
95	373–379	" " " " traces of gray clay
96	379–384	" " " " " " " "
97	384–390	Grayish black clay stratified with sand and peat (compact); pyrites
98	390–396	Fine gray sand; plastic gray clay; peat
99	396–402	" " " traces of clay
100	402–408	" " micaceous sand
101	408–414	" " " "
102	414–420	" " " " peat
103	420–426	" " " "
104	426–432	" " " " traces of clay
105	432–440	" " " " peat
106	440–447	Hard black clay
107	447–452	Fine gray sand; peat; pyrites
108	452–458	" " " traces of clay
109	458–461	" " "
110	461–468	Hard black clay
111	468–474	Fine gray sand
112	474–480	" " "
113	480–486	" and medium gray sand
114	486–492	" " " " "
115	492–498	" " " " "
116	498–504	" gray sand; soft black clay; peat; pyrites
117	504–510.5	" " micaceous sand
118	510.5–517	Hard black clay
119	517–522	Fine and medium gray sand
120	522–528	" " " " "
121	528–536	" " " " "
122	536–541	Hard black clay; pyrites
123	541–546	Grayish black clay stratified with peat and sand, compact; pyrites
124	546–552	Fine gray micaceous sand
125	552–558	" and medium gray sand; pyrites
126	558–564	" gray sand; peat
127	564–570	" " micaceous sand
128	570–576	" " " "
129	576–586	" " " "
130	586–588	" " " " traces of clay
131	588–594	" " " " " " "
132	594–600	" " " " peat
133	600–606	" " " " traces of clay
134	606–610	" " " " " " "
135	610–613	Soft light gray clay stratified with peat; peat and pyrites
136	613–618	" brownish gray clay; pyrites
137	618–622	Hard " " " peat and pyrites
138	622–628	Fine gray micaceous sand
139	628–634	" " " "
140	634–640	" " " " traces of clay
141	640–646	" " " "
142	646–652	" " " " traces of clay
143	652–658	" " " " " " "
144	658–663	Hard black clay; peat and pyrites
145	663–668	Fine gray micaceous sand
146	668–675	" " " "
147	675–680	" " " " traces of clay
148	680–685	" " " " pyrites
149	685–691	" " " "
150	691–695	Gray clay stratified with peat and sand; pyrites

TABLE 15 (*Continued*)

Well 8 (*Concluded*)

Sample	Depth Feet	Character of Material
151	695–702	Fine gray sand
152	702–708	" " "
153	708–715	" " " pyrites
154	715–721	" " " traces of clay
155	721–727	" " " peat
156	727–733	" " "
157	733–739	" " " peat; traces of clay
158	739–745	" " " "
159	745–750	" " "
160	750–756	" " " pyrites
161	756–762	" " "
162	762–768	" " " soft gray clay 10 per cent.
163	768–774	" " " pyrites
164	774–780	" " "
165	780–785	" " " traces of clay
166	785–790	" " " " " gravel; pyrites
167	790–795	" " " " " clay
168	795–800	" " " " " "
169	800–805	" " " pyrites; peat
170	805–810	" " "
171	810–816	" " " pyrites
172	816–820	" " " soft gray clay 10 per cent.
173	820–825	" and medium gray sand
174	825–830	" " " " " pyrites
175	830–835	" " " " " traces of clay
176	835–840	" gray sand; soft gray clay; pyrites
177	840–845	" " " " " " peat
178	845–851	" " " " " " " pyrites
179	851–855	Medium hard light gray clay
180	855–860	" and fine gray sand
181	860–868	" hard light gray clay; same as No. 199
182	868–873	Fine gray sand; traces of clay
183	873–876	Hard light gray clay mixed with sand and fine gravel
184	876–882	Fine gray sand; soft gray clay; pyrites
185	882–885	Hard brownish black clay
186	885–887	Medium hard light gray clay
187	887–889	" " " " " mixed with sand and fine gravel
188	889–891	Hard brownish gray and brownish black clay
189	891–897	Fine and superfine gray sand; traces of clay
190	897–900	" " " " " " " "
191	900–904	" " " " " " " "
192	904–906	" " " " " 90 per cent.; coarse gravel 10 per cent.
192b	904–906	Coarse gray gravel
193	906–909	Fine and superfine gray sand; traces of clay
194	909–914	" gray sand; soft gray clay 10 per cent.
195	914–917	" and medium gray sand; traces of clay
196	917–919	" gray sand; traces of gravel
197	919–926	" " " " " "
198	926–930	" " " " " "
199	930–931	Mixture of soft light gray clay with sand and fine gravel

TABLE 15 (*Continued*)

Classification of Samples from Test-well 192, West South Haven, Long Island. Well 100 Feet in Depth, 2 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 36.7

Sample	Depth Feet	Character of Material
1	0 – 0.5	Gravelly loam
2	0.5 – 5	Gravel: coarse 30 per cent.; fine 30 per cent.; yellow rock flour 40 per cent.
3	5–12	Gravel: coarse 30 per cent.; fine 30 per cent.; yellow medium sand 40 per cent.
4	12–19	Fine gravel 60 per cent.; yellow coarse sand 40 per cent.
5	19–21	" " 10 " " " sand: coarse 50 per cent.; medium 40 per cent.
6	21–33	Yellow sand: coarse 60 per cent.; medium 40 per cent.
7	33–40	" " " 60 " " " 40 " "
8	40–47	Fine gravel 60 per cent.; yellow coarse sand 40 per cent.
9	47–54	" " 60 " " " " " 40 " "
10	54–59	Fine gravel 20 " " " sand: coarse 40 per cent.; medium 40 per cent.
11	59–66	Yellow sand: coarse 50 per cent.; medium 50 per cent.
12	66–72	" " " 50 " " " 50 " "
13	72–79	" " " 50 " " " 50 " "
14	79–83	" coarse sand 100 " "
15	83–89	" sand: medium 50 " " fine 50 " "
16	89–95	" " coarse 50 " " medium 50 " "
17	95–99	" " medium 50 " " fine 50 " "

Classification of Samples from Test-well 342, North Moriches, Long Island. Well 99 Feet in Depth, 2 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 29.2; Ground-water, 15.1

Sample	Depth Feet	Character of Material
1	0 – 0.5	Rich yellow fine sandy loam
2*	0.5 – 7	Yellow sand: coarse 40 per cent.; medium 60 per cent.
3*	7–14	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; medium 20 per cent.
4	14–21	Yellow sand: coarse 40 per cent.; medium 60 per cent.
5*	21–28	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; medium 20 per cent.
6	28–34	Fine gravel 40 per cent.; yellow sand: coarse 40 per cent.; medium 20 per cent.
7	34–41	Yellow sand: medium 60 per cent.; fine 40 per cent.
8	41–48	" " " 60 " " " 40 " "
9	48–55	" " coarse 60 per cent.; medium 40 per cent.
10	55–62	Brown sand: medium 60 per cent.; fine 40 per cent.
11	62–69	" " coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
12	69–75	Yellow sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
13	75–81	Yellow sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.
14	81–87	Yellow sand: coarse 60 per cent.; medium 40 per cent.
15	87–94	" " fine 40 per cent.; superfine 60 per cent.
16	94–99	Yellow sand: coarse 20 per cent.; medium 60 per cent.; fine 20 per cent.

*Samples 2, 3 and 5 missing; material of these samples classified from "Boring Record"

TABLE 15 (*Continued*)

Classification of Samples from Test-well 332, East Eastport, Long Island. Well 100 Feet in Depth, 2 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 52.4

Sample	Depth Feet	Character of Material
1	0 – 0.5	Rich yellow sandy loam
2	0.5 – 6	Yellow sand: coarse 40 per cent.; medium 60 per cent.
3	6 – 12	Fine gravel 40 per cent.; yellow coarse sand 60 per cent.
4	12 – 18	" " 40 " " " sand: coarse 30 per cent.; medium 30 per cent.
5	18 – 25	Yellow sand 40 per cent.; medium 60 per cent.
6	25 – 32	White with pale yellow sand: coarse 50 per cent.; medium 50 per cent.
7	32 – 38	White with pale yellow fine sand 100 per cent.
8	38 – 45	" " " " " " 100 " "
9	45 – 52	" " " " sand: medium 50 per cent.; fine 50 per cent.
10	52 – 58	" " " " " " 50 " " " 50 " "
11	58 – 64	" " " " coarse sand 100 per cent.
12	64 – 70	" " " " sand: medium 50 per cent.; fine 50 per cent.
13	70 – 76	" " " " " " 50 " " " 50 " "
14	76 – 82	" " " " " " 50 " " " 50 " "
15	82 – 88	" " " " " " 50 " " " 50 " "
16	88 – 94	" " " " " " 50 " " " 50 " "
17	94–100	" " " " " " 50 " " " 50 " "

Classification of Samples from Test-well 337, North Westhampton, Long Island. Well 100 Feet in Depth, 2 Inches in Diameter. Elevation, B. W. S. Datum: Surface of Ground, 57; Ground-water, 15.5

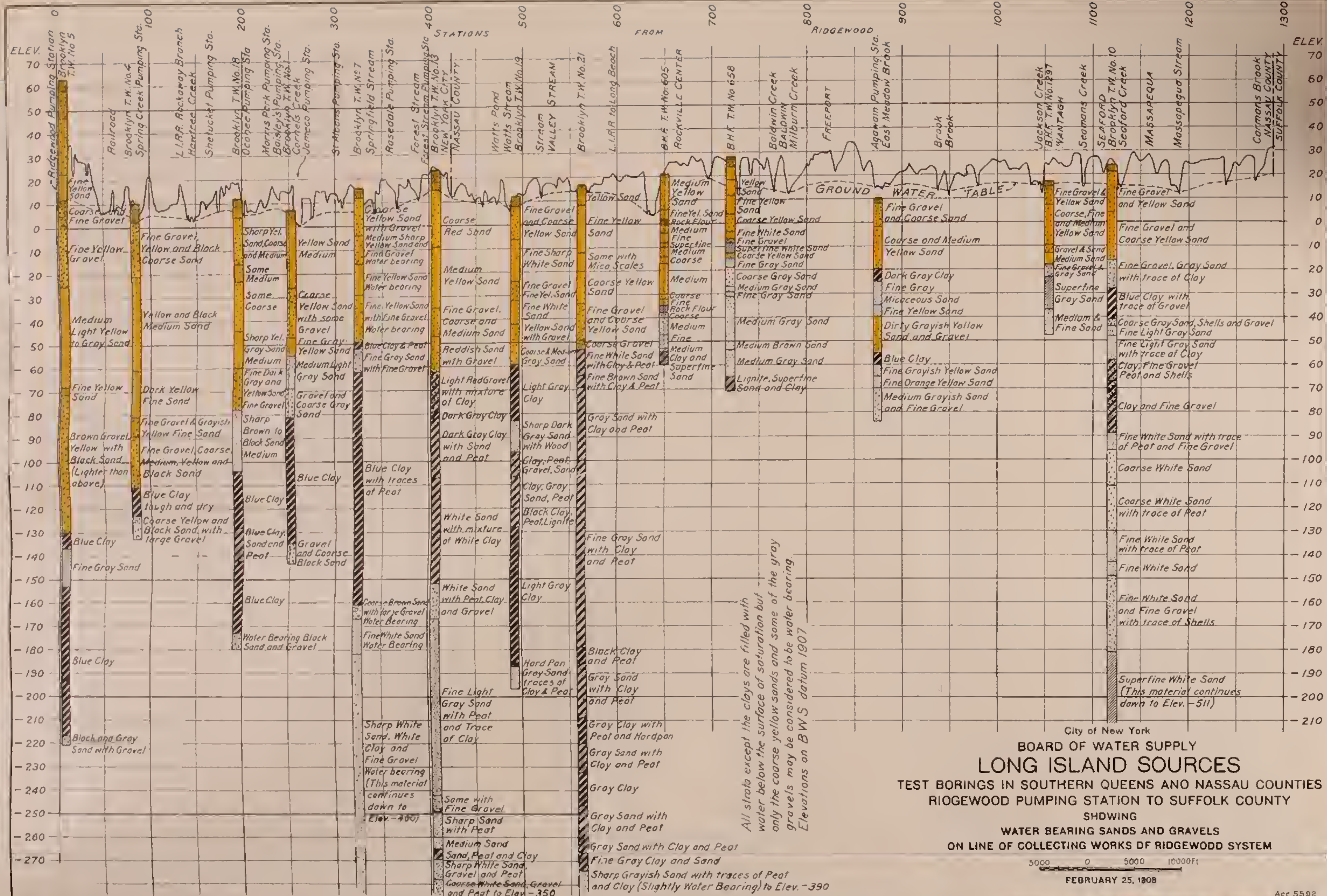
Sample	Depth Feet	Character of Material
1	0 – 0.5	Gray medium sandy loam
2	0.5 – 6	Yellow sand: medium 50 per cent.; fine 50 per cent.
3	6 – 13	Fine gravel 10 per cent.; pale yellow sand: coarse 50 per cent.; medium 40 per cent.
4	13 – 19	Pale yellow and white sand: coarse 50 per cent.; medium 50 per cent.
5	19 – 26	" " " " " " 50 " " " 50 " "
6	26 – 34	" " " " " " 50 " " " 50 " "
7	34 – 42	" " " " " " 50 " " " 50 " "
8	42 – 48	Fine gravel 10 per cent.; white with pale yellow sand: coarse 60 per cent.; medium 30 per cent.
9	48 – 55	White with pale yellow sand: coarse 50 per cent.; medium 50 per cent
10*	55 – 61	" " " " " " 50 " " " 50 " "
11	61 – 67	" " " " " " 50 " " " 50 " "
12	67 – 72	Fine gravel 30 per cent.; white and pale yellow sand: coarse 30 per cent.; medium 40 per cent.
13	72 – 80	White with pale yellow sand: medium 50 per cent.; fine 50 per cent.
14	80 – 86	" " " " " coarse 50 per cent.; medium 50 per cent.
15*	86 – 93	" " " " " " 50 " " " 50 " "
16	93–100	Fine gravel 20 per cent.; white with pale yellow sand: coarse 40 per cent.; medium 40 per cent.

*Samples 10 and 15 are missing; classification made from "Boring Record"

TABLE 15 (*Concluded*)

CLASSIFICATION OF SAMPLES FROM TEST-WELL 341, NORTH QUOGUE, LONG ISLAND. WELL 89 FEET IN DEPTH, 2 INCHES IN DIAMETER. ELEVATION, B. W. S. DATUM: SURFACE OF GROUND, 69; GROUND-WATER, 15.7

SAMPLE	DEPTH FEET	CHARACTER OF MATERIAL
1	0 – 0.5	Yellow medium sandy loam
2	0.5 – 6	" sand: coarse 40 per cent.; medium 60 per cent.; trace of loam
3	6–12	Fine gravel 20 per cent.; yellow sand: coarse 40 per cent.; medium 40 per cent.
4	12–19	Yellow sand: coarse 40 per cent.; medium 60 per cent.
5	19–25	" " " 40 " " " 60 " "
6	25–34	Fine gravel 40 per cent.; yellow coarse sand 60 per cent.
7	34–38	Yellow sand: coarse 60 per cent.; medium 40 per cent.
8	38–45	" " " 60 " " " 40 " "
9	45–52	" " " 60 " " " 40 " "
10	52–58	Fine gravel 40 per cent.; yellow coarse sand 60 per cent.
11	58–64	Yellow sand: medium 60 per cent.; fine 40 per cent.
12	64–70	" " " 60 " " " 40 " "
13	70–76	" " coarse 60 per cent.; medium 40 per cent.
14	76–82	" " " 60 " " " 40 " "
15	82–88	Fine gravel 40 per cent.; yellow coarse sand 60 per cent.



City of New York

BOARD OF WATER SUPPLY

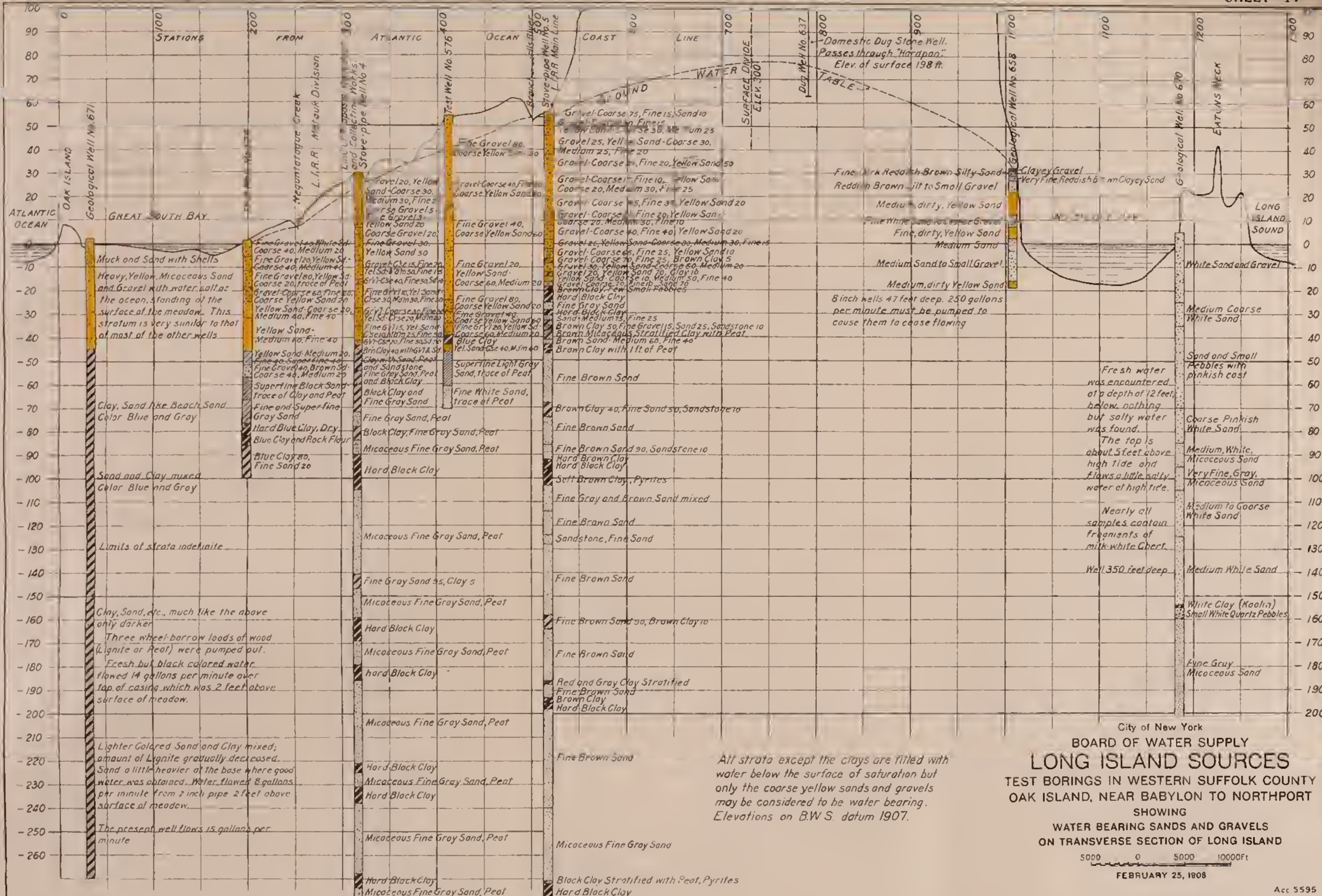
LONG ISLAND SOURCES

TEST BORINGS IN SOUTHERN QUEENS AND NASSAU COUNTIES
RIDGEWOOD PUMPING STATION TO SUFFOLK COUNTY
SHOWING
WATER BEARING SANDS AND GRAVELS
ON LINE OF COLLECTING WORKS OF RIDGEWOOD SYSTEM

FEBRUARY 25, 1908

M. B. BROWN PRINTING & BINDING CO., N. Y.

SHEET 47



City of New York

BOARD OF WATER SUPPLY

LONG ISLAND SOURCES

TEST BORINGS IN WESTERN SUFFOLK COUNTY
OAK ISLAND, NEAR BABYLON TO NORTHPORT
SHOWING
WATER BEARING SANDS AND GRAVELS
ON TRANSVERSE SECTION OF LONG ISLAND

5000 0 5000 10000 Ft

FEBRUARY 25, 1908

Acc 5595

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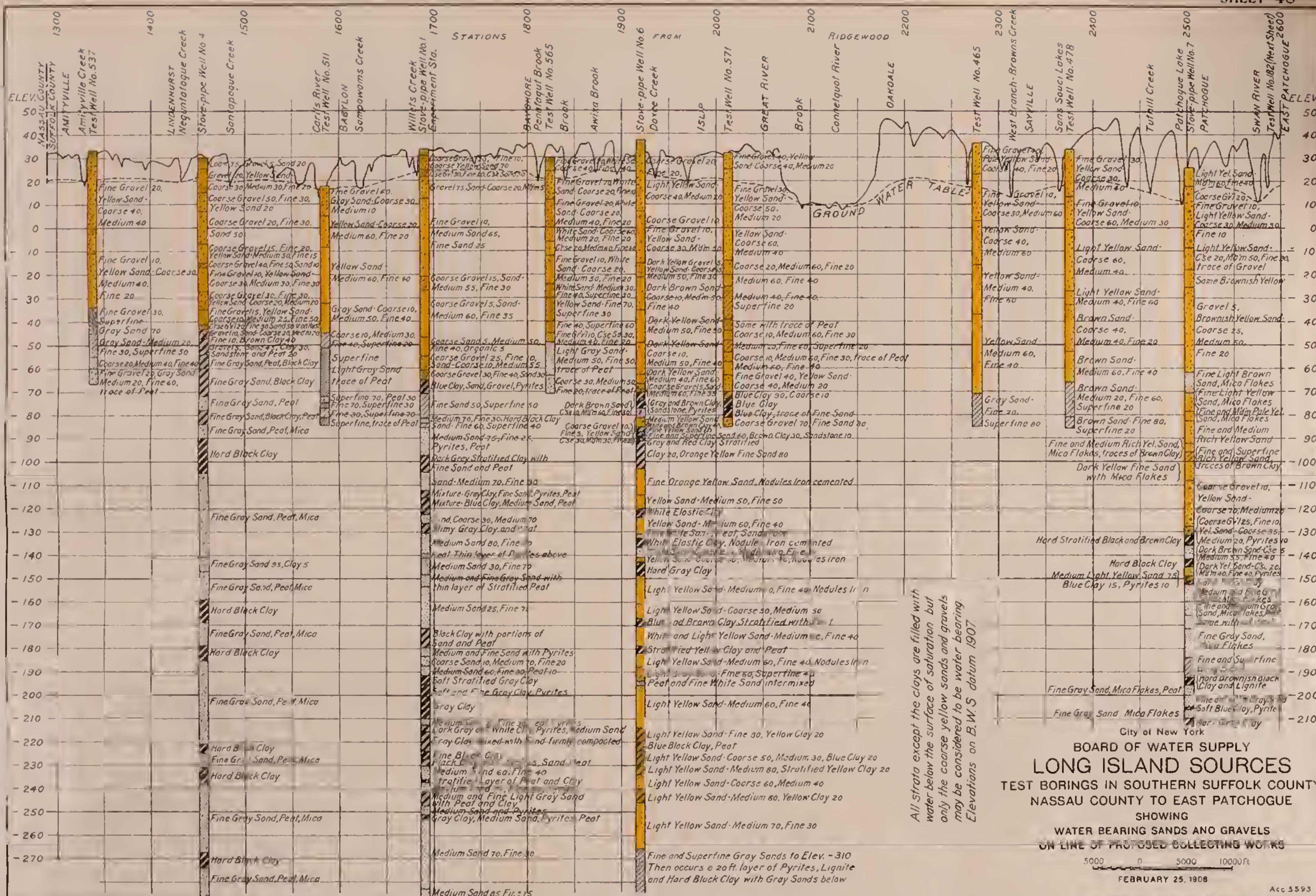

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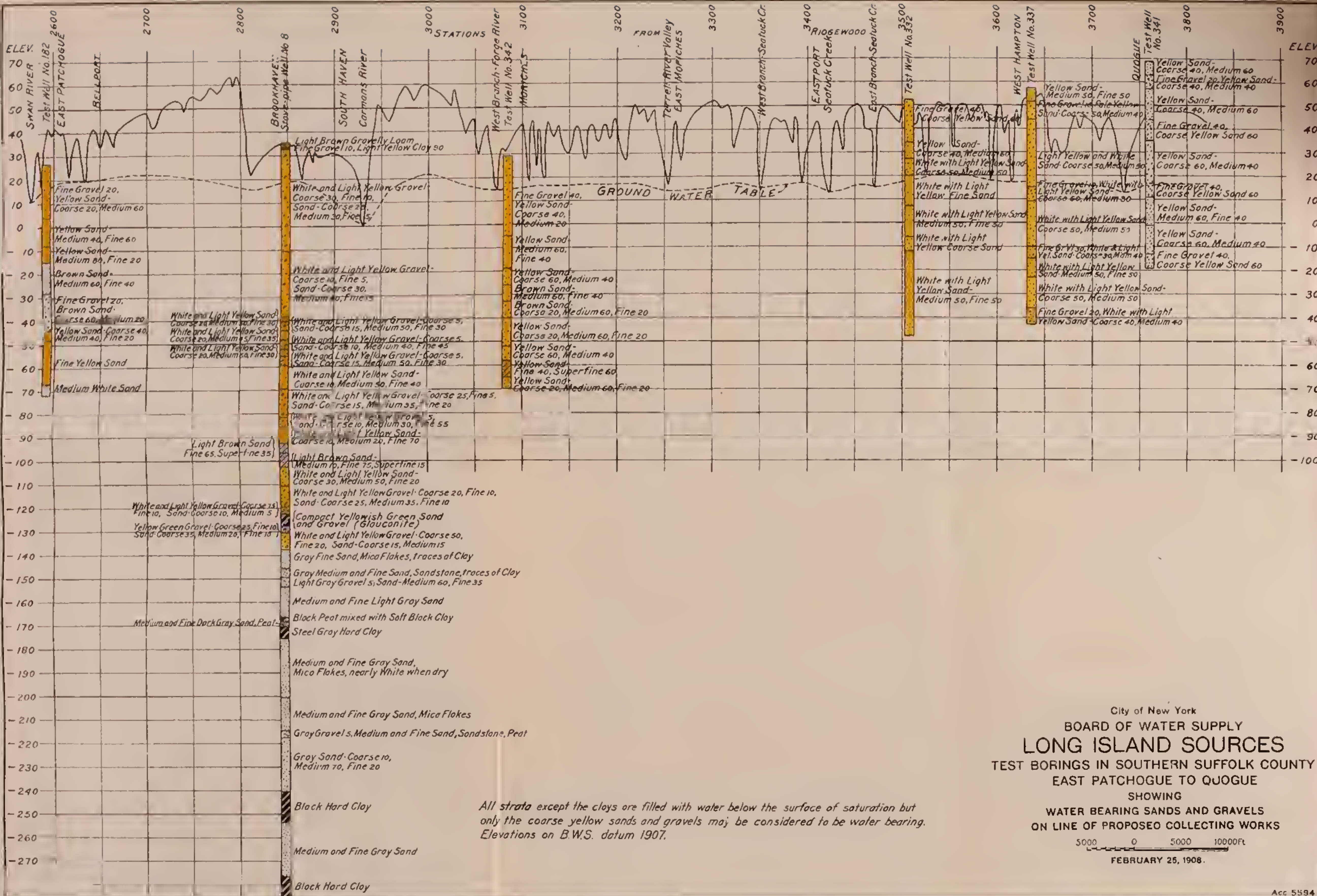


All strata except the clays are filled with water below the surface of saturation but only the coarse yellow sands and gravels may be considered to be water bearing. Elevations on B.W.S. datum 1907.

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
TEST BORINGS IN SOUTHERN SUFFOLK COUNTY
EAST PATCHOGUE TO QUOGUE
SHOWING
WATER BEARING SANDS AND GRAVELS
ON LINE OF PROPOSED COLLECTING WORKS

FEBRUARY 25, 1906.

Acc 5594

M. B. BROWN PRINTING & BINDING CO., N.Y.

APPENDIX 4

DEVELOPMENT OF SURFACE AND GROUND-WATERS OF WESTERN LONG ISLAND FOR THE SUPPLY OF THE BOROUGH OF BROOKLYN, WITH HISTORICAL NOTES ON THE RIDGEWOOD SYSTEM AND OTHER WORKS

BY WILLIAM W. BRUSH, ASSISTANT ENGINEER

In making the investigations on Long Island for an additional water-supply for New York City, the existing works now supplying the Borough of Brooklyn have been carefully studied. These works represent the largest development of ground-water in this country, and the experience that has been gained in their construction and operation is invaluable in designing the proposed Suffolk County system. Much of the data that has been collected is set forth in the following pages, with a brief historical sketch of the Brooklyn works. All this information has been obtained through the courtesy of the Department of Water Supply, whose engineers have freely given access to all their records and plans.

HISTORY OF BROOKLYN WORKS

The construction of a public water-supply system for Brooklyn was commenced in 1856, and the works were put in operation in the latter part of 1858. Prior to the installation of the water-works, a water-supply was obtained from domestic wells and cisterns within the city limits, which drew their supply from the underlying sands and gravels. The construction of the new works was the outcome of agitation covering many years, and several formal reports were made on the question of a water-supply prior to the commencement of work in 1856.

The Ridgewood System

The Nassau Water Company was formed to construct and operate the new works, the city being a stockholder in the company. In 1857 the entire rights and interest of the company were acquired by the city, and the work was completed

by the municipality in general accordance with the original plans.

The system was built under one contract, which included the distribution system, distributing reservoirs at Mt. Prospect and Ridgewood, the two pumping-stations to deliver water into these reservoirs, a brick conduit from Ridgewood to Baiseleys pond and the extension of the conduit as an open canal east of Baiseleys for a sufficient distance to insure a daily supply of 20 million New York gallons. This system, together with subsequent extensions, is now known as the "Ridgewood system."

During the construction of the works it was decided to change the open canal east of Baiseleys to a closed brick conduit, which is now designated as the "old conduit" of these works. The collecting works as originally constructed consisted of the Baiseleys, Simonsons, Clear Stream, Valley Stream, Pines and Hempstead ponds, with branch brick conduits connecting these ponds with the main brick conduit built between Ridgewood engine-house and Hempstead pond. These ponds all delivered their waters by gravity into the main aqueduct, the surface of the ponds having been raised to six to eight feet above the original stream bed. Low earth embankments were built with clay core-walls across the valleys of the streams. The works were completed sufficiently to allow water to be turned into the city mains in December, 1858, although the easterly end of the line was not finished until 1861.

The population of the city was 260,000 at the time the works were constructed, and the increase in consumption was very rapid. In 1867, when the demands of the city approached the capacity of the original works, the question of an increased supply was agitated. From this time on the water-supply of Brooklyn has seldom been more than sufficient to meet the actual requirements of the consumers, and frequently the amount of water available has been seriously inadequate, necessitating reduction in pressure to curtail the consumption.

In 1870 the construction of the Hempstead storage reservoir was commenced, and this work was practically completed in 1874. Before the reservoir was finished, however, it was found necessary to establish emergency stations at Smiths pond and Watts pond to lift the waters of these ponds into the aqueduct. These stations were in service in 1872. The

Smiths Pond plant was made a permanent station in the following year, but the Watts Pond station did not form a part of the permanent works until 1881, when this station and a similar one, constructed at Springfield pond, were placed in operation.

The Spring Creek and Baiseleys driven-well stations, which were the first ground-water plants to be used in connection with the system, were commenced in 1882 and completed in 1883. In 1884 the construction of the Forest Stream and Clear Stream driven-well stations were begun, and these were put into operation in 1885. The Jameco driven-well station was built in 1892, south of the Baiseleys pond, under a contract made in 1888.

In 1889 the extension of the Ridgewood system, including new collecting works east of Rockville Center, was authorized. The plan adopted included the enlargement of the Ridgewood reservoir by constructing Basin 3; the building of a new pumping-station at Ridgewood, located on the south side of Atlantic avenue; the laying of a 48-inch cast-iron pipe conduit from Ridgewood pumping-station to Millburn engine-house, and a 36-inch cast-iron pipe conduit from the brick conduit at Smiths pond to the Millburn reservoir; the construction of Millburn reservoir, the Millburn engine-house, and a brick conduit from Millburn engine-house to Massapequa; and the construction of five supply ponds, designated as Millburn, East Meadow, Newbridge, Wantagh and Massapequa. The Millburn pond was planned to deliver its waters directly into the pump-well at the Millburn station, the other four ponds were to deliver their supply by gravity into the brick conduit which carries the water to the Millburn station, where it is pumped to Ridgewood. These works were completed sufficiently to be utilized in 1891.

While this extension of the water-works added approximately 30 million gallons daily of surface-water to the supply, this addition was only sufficient to meet the demands of the city up to 1894. In this year an additional driven-well station was constructed at the Spring Creek site and driven wells were put in at Watts pond. In this year also a contract was made for an additional supply of not less than 25 million gallons daily of ground-water from not more than five driven-well stations east of Millburn, and a station east of Freeport, south of the East Meadow pond, was constructed at

once. Pumping was commenced in January, 1895, but the station had to be abandoned in the early part of 1896 owing to the infiltration of salt water, and was relocated about 600 feet north of the original site. In 1894 the increase in population on the drainage area of Baiseleys stream made it necessary to abandon this source of supply. During the same year the Mt. Prospect Tower service, for the high-ground around Prospect park and Greenwood cemetery, was put into operation.

It had been decided that it would be necessary to establish four stations, in addition to that at the East Meadow pond, in order to furnish the 25 million gallons daily of ground-water called for from the new watershed. The five stations, known as Agawam, Merrick, Matowa, Wantagh and Massapequa, were all in operation in 1896. These stations were all located a little south of the supply ponds on the new watershed, with the exception of the Merrick station, which was about midway between the East Meadow and Newbridge ponds. In the same year, a deep well plant was installed at Spring creek and another at Jameco station.

In 1897 the increase in pollution of the Springfield stream necessitated its abandonment, and a system of deep wells was constructed at this point and put into service at the end of the year. In the same year, the Shetucket and Oconee deep well plants were also constructed.

It was decided, in 1900, to construct filter plants to utilize the polluted waters of Baiseleys and Springfield streams, and these plants were ready for operation in 1901, but were not finally completed and accepted until 1903.

In 1903 the contract for the Wantagh infiltration gallery was let, and also a contract for filter-beds to purify the waters of Horse brook, the feeder of the Hempstead storage reservoir, which had been cut off in 1902 on account of the pollution of the stream. In 1904 a contract was made for the construction of filters for the Simonsons stream. In 1905 the contract for the Massapequa infiltration gallery was let, and work was commenced on the emergency driven-well stations at Aqueduct, St. Albans and Rosedale. These stations were required to increase the supply, which was seriously deficient in the summer and fall of that year. The Shetucket deep well plant, which, since 1899, had shown high chlorine from infiltration of salt water, was abandoned in 1905.

The three emergency stations in the old watershed, together with one at Seaford which drew its supply from the completed

section of the Massapequa infiltration gallery, were completed in 1906. In the same year, a new deep well plant was established at the New Lots station, and a contract was made to increase the deep well supply at Jameco by means of the air lift system. The contracts for the Canarsie driven-well plant were also let this year, but the station has not yet been completed.

In 1907, the Woodhaven, Shetucket and Morris Park shallow well plants were completed, and work was started on the Lynbrook and Baldwin stations. A contract was also made with S. W. Titus for 10 to 20 million gallons of water per day, from two driven-well plants located within certain limits in or near the Borough of Brooklyn. Work on these plants has been commenced, and one of them, which is located on Sixth street between Third and Fourth avenues, is in operation. The second plant, at the junction of Metropolitan avenue and Trotting Course lane, near Glendale, Long Island, is under construction.

Other Water-Works

In addition to the supply from the Ridgewood system, water is delivered to Brooklyn borough from several small driven-well stations in the 26th, 29th, 30th, 31st and 32nd wards, which were originally separate municipalities known as the towns of New Lots, Flatbush, New Utrecht, Gravesend and Flatlands. The New Utrecht Water Company supplied a part of both Gravesend and New Utrecht, their works being constructed in 1880 and purchased by the city in 1895. The works of the Flatbush Water Company were built in 1882, and are still owned and operated by the company. The system supplying New Lots was owned by the Long Island Water Supply Company and was established in 1884, the works being purchased by The City in 1900. The town of Gravesend built the Gravesend station in about 1892 as part of the sewerage system, and it became part of the city's system in 1895, after the annexation of Gravesend. The Blythebourne Water Company still supplies a portion of the 30th ward from works constructed in 1891. The German-American Company, which supplies a small portion of the 26th ward, constructed its works in 1891, and still owns and operates the plant. These were all driven-well plants for the collection of ground-water.

Table 16 gives, in chronological order, the development of the system, including both private and municipal works.

TABLE 16

SOURCES OF WATER-SUPPLY FOR BOROUGH OF BROOKLYN, WITH DATE OF UTILIZATION

Source of Supply	Date of Utilization
Baiseleys, Simonsons, Clear Stream, Valley Stream, Pines and Hempstead ponds.......	1858 to 1860
Smiths Pond station and Watts Pond temporary station	1872
Schodack brook	1873
Hempstead storage reservoir	1874
New Utrecht Water Company's well station...	1880
Springfield Pond and Watts Pond stations.....	1881
Flatbush Water Company's well stations......	1882
Spring Creek and Baiseleys well stations......	1883
New Lots well station of the Long Island Water Supply Company.....................	1884
Forest Stream and Clear Stream well stations..	1885
Millburn, East Meadow, Newbridge, Wantagh and Massapequa ponds, German-American Real Estate Company and Blythebourne Water Company's driven-well stations.......	1891
Jameco well station, Gravesend well station....	1892
Spring Creek new well station and Watts Pond well station	1894
Freeport well station	1895
Spring Creek and Jameco deep well plants, Agawam, Merrick, Matowa, Wantagh and Massapequa well stations	1896
Oconee, Shetucket and Springfield deep well stations	1898
Baiseleys and Springfield filters.............	1903
Hempstead filters	1904
Forest Stream filters and Wantagh infiltration gallery	1905
New Lots deep wells, Aqueduct, St. Albans and Rosedale well plants, and Massapequa infiltration gallery	1906
Woodhaven and Morris Park well plants and Shetucket shallow well plant	1907

Of the sources of supply given in this table, the following have been abandoned on account of pollution and infiltration of sea-water:

In 1894, Baiseleys pond
" 1895, Freeport well station
" 1897, Springfield pond
" 1902, Horse brook (feeder to Hempstead storage reservoir)
" 1904, Simonsons pond
" 1905, Clear Stream pond and Shetucket deep well station

The surface supplies were polluted by the population on their watersheds, and were subsequently utilized by the construction of filter-plants, with the exception of the Clear Stream pond. The well stations were permanently abandoned because of the entrance of salt water from the south shore bays which cannot be removed from the supplies.

DESCRIPTION OF RIDGEWOOD SYSTEM

The Ridgewood system is by far the most important of the works supplying Brooklyn borough with water, and this system is to be briefly described in the following pages.

CHARACTER OF WATERSHED

The drainage area tributary to the Ridgewood system extends from the borough limits easterly to approximately the Suffolk County line. The watershed is bounded on the south by the marshes and tide-waters of Jamaica and Hempstead bays, and on the north by the ground-water summit which, in a general way, follows the surface divide.

The northerly portion of the watershed within the hills, which represent the terminal moraine of the great North American glacier, is covered by a rather fine, compact and somewhat impervious soil. The greater part of the watershed is within the broad sandy plain, which gently slopes from the hills in the central part of the island southerly to tide-water. The surface soil covering is usually light and very

pervious, and ordinarily overlies coarse yellow sands and gravels, said to be of glacial origin. Below these occur gray sands and gravels separated by strata of clay of varying thickness which extend to bed-rock at a depth of 500 to 1100 feet or more. The borings show that these clay beds are not continuous; some of them cover several square miles in area and others are of very limited extent.

The upper limit, or surface, of the saturated sands and gravels is shown on Sheet 1, Acc. 5530, which has been redrawn on the B. W. S. datum from the report of the Burr-Hering-Freeman Commission. All the sands and gravels below this surface of saturation are filled with ground-water, and the southerly slope of this surface of approximately 10 feet to the mile shows the general direction of ground-water movement. The water under the clay beds near the shore line usually rises to a hight of about five feet above the surface of the ground-water in the surface sands, probably due to the greater pressure against which the deeper ground-water has to discharge. There are places in Jamaica and Hempstead bays where the discharge from the sands forms fresh-water pools, and it is stated that the water is sufficiently fresh to be palatable. As the water in the deeper strata must discharge into the sea at some depth below its surface, the extra weight of the salt water would cause this increased head or artesian condition.

COLLECTING WORKS

The collecting works of the Ridgewood system are situated on the southerly limits of the watershed just north of the salt marshes and the heads of the salt-water estuaries of the creeks entering the south shore bays. These works intercept both the surface flow of the streams and the southerly moving ground-waters in the water bearing sands and gravels.

Surface Supply

All streams on the watershed having a dry weather flow of over a million gallons a day have been utilized. Small supply ponds have been constructed on these streams and the water has been delivered into the conduit lines either by gravity or by means of pumping-plants. The elevation of the waste-weir of each of these ponds, the area and storage ca-

pacity at this elevation, and the area of each tributary watershed, are given in the table below:

SUPPLY PONDS AND STREAMS OF RIDGEWOOD SYSTEM

Stream or Pond	Elevation of Waste-Weir Feet B. W. S. Datum	Elevation of Lowest Point of Draft Feet B. W. S. Datum	Area of Pond at Elevation of Waste-Weir Acres	Available Capacity of Pond at This Hight Million Gallons	Area of Tributary Watershed Square Miles
OLD WATERSHED					
Baiseleys pond	11.3	6.1	40.0	41.9	8.3
Springfield pond	6.8	1.7	7.3	7.2	3.8
Simonsons pond	18.7	13.1	8.8	9.9	6.4
Clear Stream pond	14.9	10.2	1.1	1.0	1.5
Valley Stream pond	16.3	10.6	17.8	20.9	9.5
Watts pond	8.3	2.8	3.4	3.8	...
Pines pond	15.4	9.6	8.0	9.0	5.4
Schodack brook	...	...	...	...	...
Hempstead storage	32.2	13.2	237.6	860.0	...
Hempstead pond	13.9	8.4	23.5	26.9	17.0
Smiths pond	6.8	0.3	27.3	41.6	...
Total	...	...	...	**1,022.2**	**51.9**
NEW WATERSHED					
Millburn pond	8.3	4.0	13.6	11.1	3.5
East Meadow pond	9.4	3.8	16.2	18.8	19.5
Newbridge pond	10.2	4.2	8.9	11.4	3.3
Wantagh pond	11.4	4.9	10.1	15.0	17.6
Massapequa pond	12.9	7.4	14.6	17.0	20.7
Total	...	...	...	**73.3**	**64.6**

The total surface storage corresponds to $\frac{1095.5}{116.5} = 9.4$ million gallons per square mile

The pollution of the surface-waters, due to increase in population on the watershed, necessitated the temporary abandonment of five streams, viz., Baiseleys, Springfield, Simonsons, Clear stream and Horse brook, of which all but Clear stream, the smallest supply, have been subsequently utilized by filtering the water. The flow of Clear stream was indirectly utilized by the Clear Stream driven-well station.

Hempstead pond will not deliver water at sufficient elevation to flow into the conduit at the hydraulic gradient usually maintained at the east end of the conduit, and the water from this pond flows into Smiths pond below and is pumped at the Smiths Pond station.

No continuous gagings of these surface streams have been made, but several series of measurements have been taken during periods of drought. On the new watershed, the gagings were made prior to any ground-water development; but on the old watershed the ground-water had been partially

developed prior to 1888, although not to a sufficient extent to materially affect the surface flow. The subsequent collection of a large ground-water supply has reduced the flow of the surface streams, and this flow will be still further reduced by the proposed additional ground-water works.

The dry weather yield of the streams and ponds, as shown by the gagings, is given in the table below:

MINIMUM FLOW OF STREAMS, IN MILLION GALLONS DAILY

Stream or Pond	1856 and 1857	June 1 to October 15, 1883	September 19 to October 12, 1885	August 30 to October 5, 1894
		OLD WATERSHED		
Baiseleys	2.9	...	...	...
Springfield	0.6	...	...	...
Simonsons	1.8	...	1.3	2.0
Clear stream	0.7	...	...	0.2
Valleystream and Watts pond	2.3	...	1.9	1.3
Pines pond	2.5	...	1.1	0.6
Schodack brook	...	...	0.7	1.0
Hempstead pond, Hempstead storage reservoir, Smiths pond	7.3	...	7.1	8.0
		NEW WATERSHED		
Millburn	...	1.9	...	...
East Meadow	...	5.2	4.2	...
Newbridge	...	1.2	...	...
Wantagh	...	3.4	...	...
Massapequa	...	3.1	...	...

The estimated yield of the surface streams during periods of normal rainfall, with continuous operation of the ground-water stations, has been shown in Table 1, page 63, and the actual yields of the surface streams for 11 years are shown in Appendix 1, in discussing the yield of the Long Island watersheds. The present safe yield of these streams is less than that shown by the gagings because of the diversion of water from the streams by the ground-water collecting works.

The construction of the Millburn reservoir was included in the original plans for developing the surface supply east of Rockville Center, it being intended to utilize this reservoir to store a portion of the surface flow during wet seasons, and draw on stored waters during periods of drought. The reservoir was not water-tight, and it has been impossible to use it since its completion, about 1893. There appears to be no justification for any further outlay on this structure as it is both unnecessary and inadvisable to make it a part of the present Ridgewood system.

Since the construction of the ground-water collecting works in the new watershed, both surface and ground-waters have been delivered to the Millburn pumping-station, and these mixed supplies would be stored in the Millburn reservoir if it were to be used now. The experience of the past 10 years has, however, shown that it is inadvisable to attempt the storage of ground and surface-waters in open reservoirs. Mixed waters that have been thus stored elsewhere in the Ridgewood system frequently become unsatisfactory to the consumers on account of the rapid development of microscopic organisms, which impart to the water an offensive taste and odor, although the organisms are not apparently detrimental to health. For this reason the Millburn reservoir should not be utilized unless it is to be covered, and the cost of a covered reservoir is prohibitive.

The amount of surplus water in the new watershed that could really be utilized by the Millburn reservoir for a complete development of the underground supply is extremely small, as shown by the record of waste during the years 1906 and 1907, on Sheet 50, Acc. LJ 186. Of the waste recorded, 363 million gallons were due to the pollution of the East Meadow stream from July 29 to September 15, 1906, and the consequent cutting out of the stream from the supply during this period. In November of 1907, 17 million gallons were also wasted for the same reason. After making this correction in the waste recorded, the remaining waste on the new watershed amounted to only 169 million gallons in 1906 and 145 million gallons in 1907, or an average of 0.43 million gallons daily for the two years.

The surface formation of western Long Island is not favorable to the economic development of surface storage for water. The Millburn reservoir has already cost about $1,100,000, and was designed to store 373 million gallons, making the cost of construction nearly $3,000 per million gallons stored. The interest and sinking fund charges on this amount would make the cost of water obtained from this reservoir very high. Assuming that the reservoir be filled once a year, the cost for fixed charges would be about $150 per million gallons, or about double the average cost of collecting and distributing the entire supply. The Hempstead storage reservoir cost about $2,000 per million gallons stored, and if the full contents of this reservoir be utilized each

year, the cost per million gallons for fixed charges would be about $100.

The natural result of the increase in population on the watershed will be the abandonment of the surface streams as sources of supply, or the complete filtration of their waters. This filtration can be economically and efficiently secured by developing the underground supply and reducing the amount of water entering the streams. The water which does reach the streams can be made to re-enter the sands through the beds of the streams and ponds and eventually reach the underground collecting works.

Some flood flows must necessarily be lost with any economical system of collection, but the amount of water so lost would be extremely small, as shown by the actual waste from the new and old sheds plotted on Sheet 7, Acc. LJ 148. With an increase in consumption and in capacity of conduit, the amount of surface-water wasted would be greatly reduced.

Ground-Water Supply

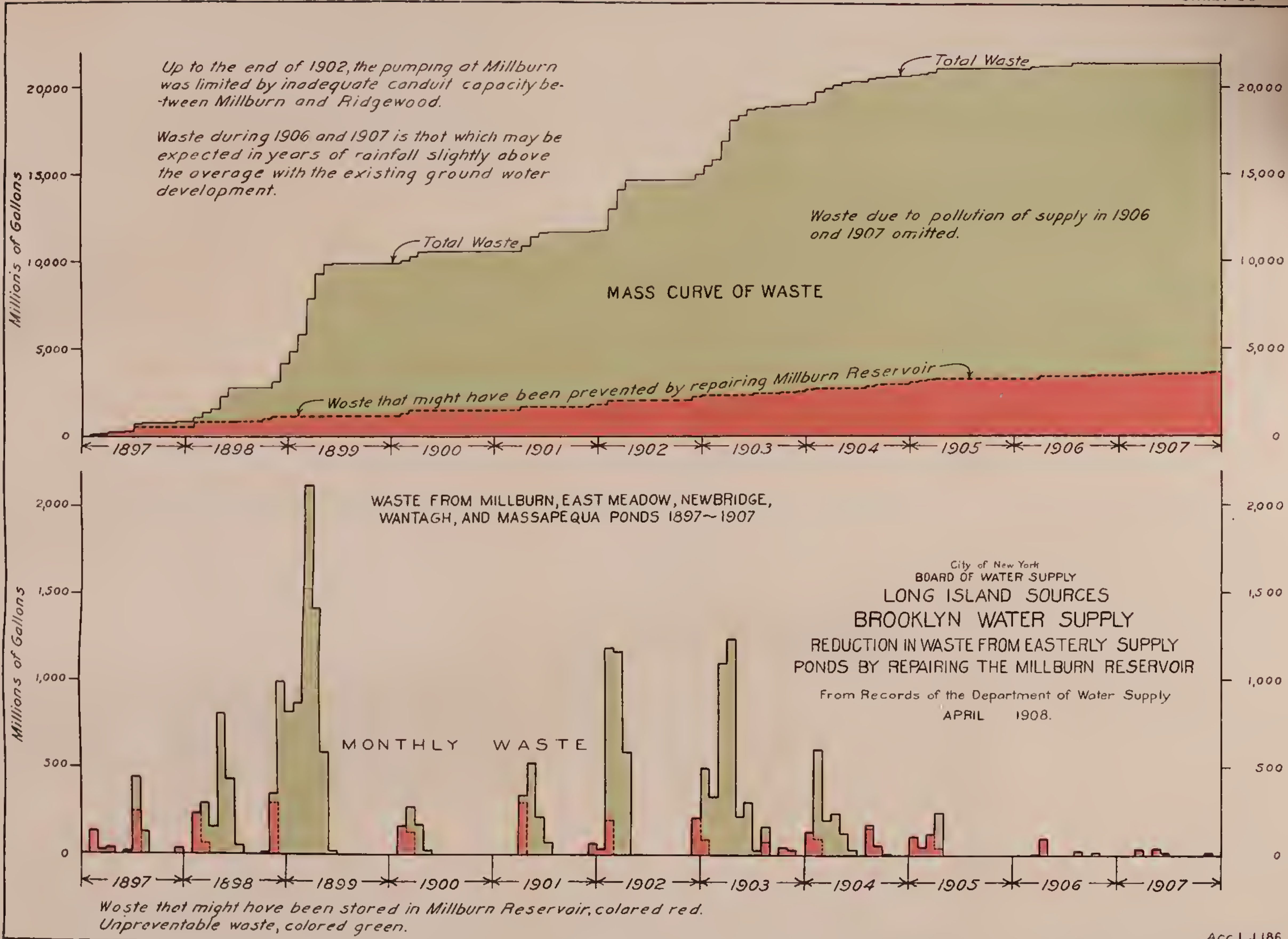
A partial development of the ground-waters of Long Island for the Brooklyn supply was first proposed in the original plan for the works, it being intended to construct an open canal east of Baiseleys pond below the ground-water level and allow the water to seep into the canal. The abandonment of this proposed canal and the substitution of a closed conduit eliminated any ground-water from the original system. The need of additional supply made it necessary, however, to utilize later all sources that might be made readily available, and the ground-waters have, therefore, been developed from time to time to meet the urgent demands for additional water-supply. The method of development has included large open wells, small tubular wells connected in gangs or groups to a central suction main, and infiltration galleries.

Well Systems

(See Sheets 51 and 56 Accs. LJ 187 and LJ 193)

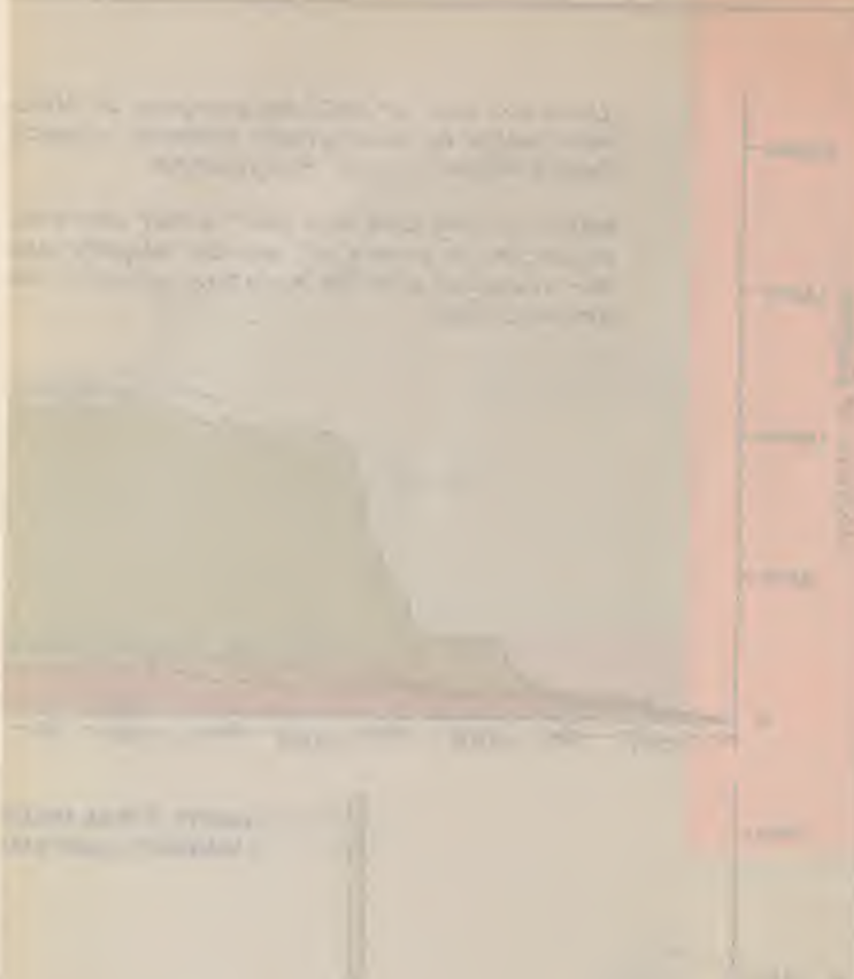
OPEN WELLS

At the Smiths Pond, Watts Pond and Springfield Pond stations, open, brick-lined, circular wells, 50 feet in diameter, were originally constructed, the bottom of the wells being about ten feet below the normal ground-water



Acc. L. J. 186.

M. B. BROWN PRINTING & BINDING CO., N. Y.



surface. By lowering the water-level in the well, it was expected that water would be drawn in from the surrounding sands and thus increase the yield at these stations. It was found, however, that as the water-level was lowered, the fine sand entered the well, undermining the sides and endangering the stability of the pumping-station building. The amount of water obtained, therefore, by the construction of these large wells has been very small.

DRIVEN WELLS

The first tubular wells used in connection with the Brooklyn supply were 2-inch wells, driven by Andrews & Co., in groups or gangs, under a patent covering this type of construction. The wells which were driven in the old watershed consisted of 2-inch iron pipe in 5-foot lengths, with a 2-inch strainer and a drive point. The strainers were about seven feet in length and were covered with a slotted brass gauze. The average depth to which the wells were driven was about 35 to 40 feet, a small hand rig being used, having a 150-pound hammer with an effective average drop of about five feet. The wells were located about 12 feet apart along the line of the suction mains, and were driven in pairs, on opposite sides of the main suction line, and about 12 feet from the center on either side. The top of the well had a 2-inch by 3-inch head, with a 3-inch pipe connecting the well with the main suction, a valve being provided on each suction arm so that any individual well could be cut out of service. The number of wells driven at each station varied from 100 to 180. The general arrangement of the wells, together with details of the point and strainer used, are shown on Sheet 51, Acc. LJ 187. The Spring Creek, Baiseleys, Jameco, Forest Stream and Clear Stream plants were originally equipped with these wells, the first contract for the wells being made in 1882 and the last in 1888.

To replace the worn out 2-inch points and strainers driven by Andrews & Co., the city purchased 2-inch points and strainers, made of galvanized-iron pipe, with holes punched in the pipe, covered by a thin slotted brass sheet or gauze The details of these strainers and points are shown on Sheet 51, Acc. LJ 187.

In 1894, three contracts were made for new driven-well plants, in both the old and new watersheds. The well in-

stalled under these contracts consisted of 4½ to 6-inch strainers and casings, sunk with open ends by means of washing or sand-bucketing the material from the interior of the pipe and allowing the well to sink by its own weight, turning the well to reduce the friction. The wells were provided with various lengths of strainers, in general being about 10 feet, and they were connected to the main suction pipe by a branch suction pipe about 1½ inches smaller than the well casing, with a drop suction of the same size within the casing. The main suction was laid approximately at right angles to the line of flow of the underground waters, and in both directions from a central receiver. Wells were driven alternately to the north and south, at intervals of from 30 to 40 feet, and approximately 10 feet from the main. At the Spring Creek station the wells were placed about 40 feet on either side of the central main. Sheet 51, Acc. LJ 187, gives a typical plan of these well systems and the details of strainers used by Edwards & Company in installing the Agawam, Merrick, Matowa, Wantagh and Massapequa stations. At these stations the strainers were of cast phosphor bronze, ribbed type, as shown on the plan, with the exception of a few wells which had the brass pipe strainers. At Watts Pond station, Edwards & Company used perforated iron pipe with countersunk holes, the pipe being covered with brass gauze. The five stations east of Millburn, together with the Watts Pond station, were included in two of the three contracts made in 1894, the third being for wells at the Spring Creek station, where an iron strainer from 7 to 14 feet in length, covered with brass gauze and surrounded with gravel, was used. The location of the wells at Spring creek is also shown on Sheet 51, Acc. LJ 187.

About 1896 the Department of Water Supply commenced sinking wells with its own men and put in the deep well plants at Jameco, Springfield, Oconee, Shetucket and Spring creek. The material found below the clay bed was generally coarser than that above, and the wells were driven with 8-inch casing and iron strainers. The strainers were of standard wrought-iron pipe, provided with a cutting shoe, made up of a standard coupling cut to form V-shaped teeth, and were perforated with holes drilled from ⅛ to 3/16 inch in diameter. About 10 feet of the casing were thus perforated and no outside covering was placed over the holes. The wells were

sunk by turning and washing, or sand-bucketing, the material from the interior of the well, the weight of the casing being sufficient to sink the well. The depth of these wells was usually from 130 to 200 feet. Details of the deep well point used by the department are shown on Sheet 51, Acc. LJ 187.

Since about 1902, 6-inch wells have been used by the department, with strainers made up of galvanized-iron pipe, with circular or elliptical holes punched or bored in the pipe, the pipe being covered with perforated brass, as shown on Sheet 51, Acc. LJ 187. These wells have been used at different stations, but none of the stations has been entirely equipped with them.

In 1905 a change was made in the method previously followed in constructing the shallow wells. A casing of 12 to 18 inches in diameter was first sunk to a depth two or three feet below the level at which the bottom of the well was to be placed, and gravel filled in to that level. The well and strainer were then placed within the casing, the annular space around the well filled with gravel, and the casing withdrawn as the gravel was placed. Various types of strainers have been used for these wells. Several of the Edwards strainers, which had been pulled out, were covered with the slotted brass and used in the new type of well, but failed after about a year's use, due to the wearing out of the brass cover. The 6-inch strainers of the department were also tried, two of the strainers, however, being coupled together to make a screen section about 24 feet in length.

The use of the outside casing with gravel surrounding the well was adopted primarily for a tile well. This well is constructed by first sinking the casing and filling in with gravel to a depth of about two feet; a cast-iron bottom plate with a wooden cover is attached to a rod, and perforated tile pipe placed on the wooden form. The joints of the tile pipes are run with melted sulphur, and the pipes are centered around the rod by means of small wooden braces. The rod is made in sections, with joints about every 10 feet, so that it can be lowered into the well and additional sections attached as required. The perforated tile is usually carried up for a distance of from 20 to 30 feet above the bottom plate, and the well is then completed with a standard tile pipe. When the tile pipes have been built up to a length slightly greater than the depth from the surface to the gravel at the

bottom of the casing, the well is lowered until it rests on the gravel at the bottom. Additional gravel is filled in around the casing and the well is carried up to about the ground-water level. As this gravel is filled in, the casing is withdrawn, and finally the rod is taken out by unscrewing it from the nut which is held in a socket in the bottom plate. The small wooden sticks used to center the tiles are loosened and float to the surface of the water. An iron drop suction with a T-head completes the well. With a 12-inch outer casing, 4½-inch slotted pipes enlarging at the top to 6-inch standard pipes are used to form the wells. With 14 and 18-inch outer casing, 6-inch and 8-inch pipes, respectively, are used for the full length of the well. Sheet 51, Acc. LJ 187, shows details of the casing, the vitrified strainer, and the method of construction of the tile well.

A solid brass strainer, manufactured under the Johnson patent, has been used since 1905, both for deep and shallow wells. This strainer is made up of a narrow perforated brass ribbon, rolled up spirally, the inside edges of the ribbon being rolled together. The width of slot can be varied as desired, the slots used by the department ranging from .017 inch to .025 inch. The strainers are made up in 10-foot lengths and two strainers coupled together. This strainer is not strong enough to be sunk with the casing, as is done with the pipe strainers. The casing for deep wells is, therefore, sunk to the full depth of the well, the strainer inserted, the casing pulled up to approximately the top of the strainer, and the space between the strainer and the well closed by means of a well packer. The casing is left in place and forms the upper part of the well from the strainer to the ground surface. A number of these strainers have also been used for shallow wells. In such wells they have been placed within a 12-inch outside casing and surrounded by gravel, after which the outer casing is removed. On Sheet 51, Acc. LJ 187, are shown details of this strainer.

In the latter part of 1905 and the early part of 1906, six tile wells were sunk by Messrs. Elliot & Marren. Five of these wells were located at temporary stations along the line of the Massapequa gallery and were only in service for a short time. One well was sunk at the Matowa station and has since been used with the other wells at this station. The Elliot & Marren well consists of 18-inch vitrified tile pipe with

the lower 8 to 12 feet of tile perforated with circular or rectangular openings, thus forming a strainer. The tile is placed on a cast-iron shoe, which extends about three inches outside of the tile pipe, and as the well is sunk the gravel is placed around the well, it being expected that the gravel would follow the well as the sinking progresses. The material from the interior of the well is removed by sand-bucketing and the well is sunk by placing weights on a timber lever pressing on the top of the pipe. Only a comparatively small weight is required in addition to its own weight, to sink the well.

The preceding description of the wells used by the Department of Water Supply covers all types in general use, but the records of the department do not give a full description of all the wells, and there are probably some forms of strainers used that have not been described. Table 17 gives a summary of the wells in use at the various stations in 1906.

Comparative Merits of Several Types of Wells

As has already been stated, the open wells yielded an extremely small amount of water for their size and cost, and they were soon abandoned for the driven or pipe type of well.

With the 2-inch wells, as installed by Andrews & Co., it was possible to obtain between four and five million gallons daily from 100 to 150 wells where the location was favorable. These wells lasted about six to eight years without serious clogging, when a continuous draft was maintained. If the draft from the wells was frequently interrupted, the wells would fill with fine sand and iron oxide, and show a consequent reduction in the yield. The 2-inch points put in by The City to replace the Andrews wells had a much shorter life, the wells clogging in one or two years' time, necessitating pulling and cleaning or replacing of the wells. An individual well when first driven would yield, with hand pump, from 35 to 75 gallons per minute. The average yield of the stations where these wells were driven has been about three million gallons daily, or about 15 to 20 gallons per minute per well.

The 4½ and 6-inch wells put in by Edwards & Co. required frequent cleaning in order to maintain their yield. Stations consisting of from 30 to 60 wells yielded about five million gallons daily. On the basis of 40 wells to a station,

TABLE 17

STATION	Date of Construction	Suction Main Size	Suction Main Length	Wells	Number	Casing	Drop Suction	Strainer	Length of Strainer	Depth Max.	Depth Min.	Depth Aver	Method of Determining Yield	Yield (In Gallons per Day) Shallow Wells	Deep Wells	Total
New Utrecht	1885	16"-12"	545'	Shallow	20	6"	4"									
" " "	1897	12"	250'	" "	40	2"		Brass Gauze Covered Perforated Iron Pipe	5'			35'	Pump Displacem't	1,500,000		1,500,000
Gravesend	1891	12"	600'	" "	113	2"		" " "	5'	40'	35'	37½'	" "	2,200,000		
" " "	1905 1906	12"	187'	" "	6	6"		" " "	20'			55'	" "	1,000,000		3,200,000
New Lots	1881	4"-6"-6" 10"-12"-16"	1600'	" "	22 14	2" 6"		" " "					" "	3,200,000		
" "	1903 1904			Deep	5	8"	5"	4½" & 5" Brass	Aver 12'	162'	136'	145'	" "		300,000	3,500,000
Spring Creek P.S.	1882	12"-15"	625'	Shallow	100	2"		Brass Gauze Covered Perforated Iron Pipe	7'			35'		Out of Service		
" " "	1897	12"-15"	730'	Deep	10	8"	5"	Perforated Iron Pipe	10'±			180'	Weir		500,000	
" " "	1905	12"-15"	625'	Shallow	5	4"		Brass Gauze Covered Perforated Iron Pipe					"			
" " "	"	" "	"	" "	8	4" to 6"	4"-4½"	4" Slotted Tile Pipe	30'			61'	"			
" " "	"	" "	"	" "	5	4½"		Brass Frame Covered with perforated Brass "Edwards"	24'			58'	"	5,250,000		8,000,000
" " "	"	" "	"	" "	3	6"		Brass Gauze Covered 6" Perforated Iron Pipe	24'			65'	"			
" " " Temporary	1894	12"	230'	" "	13	6"	4½"	Perforated Brass	21'-28'	68'	37'	45'	"	2,250,000		
Aqueduct	1905-6	12"-16"	420'	" "	15	6"		Brass Gauze Covered Perforated Iron Pipe	24'			55'	"	3,000,000		3,000,000
Shetucket	1897	12"-15"	675'	Deep	12	8"	5	Perforated Iron Pipe	10'±					Out of Service		
Oconee	1903	12"-15"	670'	Shallow	40	2"		Brass Gauze Covered Perforated Iron Pipe	5'			35'	"			
" "	1905			" "	4	4"		" " "	10'			55'	"	1,600,000		
" "	"			" "	2	6"		" " "	12'-24'	65'	45'	55'	"			3,400,000
" "	1897	12"-15"		Deep	12	8"		Perforated Iron Pipe	10'±			195'	"		1,800,000	
Baiseleys	1883			Shallow	100	2"		Brass Gauze Covered Perforated Iron Pipe	5'-7'			30'	Pump Displacement	1,400,000		1,400,000
Jameco	1890	12"-24"	865'	" "	183	2"		" " "	5'-7'			35'	Weir	Out of Service		
" "	1905			" "	4	8"	6"	8" Slotted Tile Pipe	40'			50'	"	1,800,000		4,000,000
" "	1897	12"-20"	860'	Deep	12	8"	5"	Perforated Iron Pipe	10'±			152'	"		1,200,000	
" "	1891 to 1894			" "	9	8"	5"	" " "	10'±			152'	"		1,000,000	
" "				" "	1	10"	5"	" " "	10'±			160'	"			
St Albans	1905-6	12"-16"	620'	Shallow	20	6"		Brass Gauze Covered Perforated Iron Pipe	24'	55'	46'	50'	"	3,000,000		3,000,000
Springfield	1897	12"-20"	700'	Deep	20	8"	5	Perforated Iron Pipe	10'±			163'	Pump Displacement		3,000,000	3,000,000
Rosedale	1905-6	12"-16"	560'	Shallow	20	6"		Brass Gauze Covered Perforated Iron Pipe	24'	55'	46'	50'	Weir	3,000,000		3,000,000
Forest Stream	1884	12"-15"	880'	" "	102	2"		" " "				41'	Pump Displacement			
" " "	1906	" "	"	" "	3	6"		" " "				54'	" " "	3,000,000		3,000,000
" " "	"	" "	"	" "	1	6"		6" Brass ("Johnson")				52'	" " "			
Clear Stream	1884	12"-15"	1200'	" "	142	2"		Brass Gauze Covered Perforated Iron Pipe				38'	Weir	3,000,000		3,000,000
" " "	1906			" "	4	6"		" " "				54'	"			
Watts Pond	1895	10"-12"-16"	590'	" "	12	6"	4½"	" " "				50'	Pump Displacement	2,000,000		2,000,000
Agawam	1895	20"-18" 16"-14"-12"	1579'	" "	32	6"	4½"	Brass Frame Covered with Perforated Brass "Edwards"	10'	79'	33'	56'	Weir	3,000,000		3,000,000
Merrick	1895	8"-18"	2340'	" "	60	6"	4½"	" " "	10'			39'	"	2,700,000		
" "	" "	" "	"	Deep	2	6"	4½"	" " "	10'			108'	"		300,000	3,000,000
Matowa	1895	8"-14"	1765	Shallow	31	6"	4½"	" " "	10'			38'	"	1,000,000		
" "	" "	" "	"	Deep	15	6"	4½"	" " "	10'			97'	"		2,000,000	3,000,000
Wantagh	1895	8"-24"	2175'	" "	28	6"	4½"	" " "	10'			90'	"		3,000,000	3,000,000
Massapequa	1895	8"-16"	1960'	Shallow	43	6"	4½"	" " "	10'			38'	"	1,300,000		
" " "	" "	" "	"	Deep	10	6"	4½"	" " "	10'			106'	"		2,700,000	4,000,000
													Total	45,200,000	15,800,000	61,000,000

Data given is based on conditions existing in 1906.

Shallow Wells are those drawing their supply from upper sand strata.

Deep Wells are those drawing their supply from strata below a clay bed.

The Yield given is the normal amount pumped when the station is in operation.

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
DRIVEN WELL SYSTEMS
From Records of the
Department of Water Supply
FEBRUARY 25 1908

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this would be equivalent to between 80 and 90 gallons per minute per well. A number of these wells failed after about eight years' intermittent use, by the breaking of the brass sheet metal covering the openings, and the perforations in the covering were worn in some cases to nearly double their original diameter. The brass slotted screens which were used to re-cover the strainers placed on wells surrounded by gravel lasted only from one to two years before breaking.

The deep wells driven by the department yielded freely at first, 12 wells giving from three to five million gallons daily. These wells, however, filled with sand, the yield decreased materially after about a year's use. After the wells were cleaned by removing the sand, it was found that the original yield could not be obtained. This type of strainer has not, on the whole, been successful. The 6-inch iron strainer covered with perforated brass has also failed, even when surrounded with gravel. The openings in the brass become clogged, and after one or two years' use the yield of the wells is reduced so that wells have to be pulled.

Among the different types of wells used by the department, the tile well and the solid brass strainers, with gravel, have given the best results. The yield of these wells, when pumped separately, has been from 250 up to 700 gallons per minute, and 15 to 20 wells would yield from four to five million gallons daily.

The tile well has given some difficulty in construction, owing to the weakness of the perforated tile. In 20 per cent. of these wells, the tiles have probably had to be replaced during construction, because of breakage during the building up of the wells prior to the filling in of the gravel. The only loss occasioned thereby has been the value of the tile and the time spent in placing the same.

An examination made of a tile well at the Spring Creek station, after it had been in use about two years, showed it to be entirely free from any material that would tend to clog the well or reduce the flow. An inspection of another tile well at the Jameco station, which had been in use slightly over two years, showed it to be filled to a depth of about 35 feet with a deposit of iron oxide, clay and fine sand, which has somewhat reduced the discharge of the well. The iron in the waters at the Jameco station has, however, always given trouble, and has caused wells of other types to fill up and clog much more rapidly than at other stations.

There has been no apparent diminution in the yield of the wells using the solid brass strainer, but these have not been in service sufficiently long to determine whether this type of strainer will give permanently satisfactory results. The strainer is not structurally strong enough to allow it to be removed and replaced without danger of destroying it.

Cost of Wells

The wells put in under the Andrews' patent were paid for on the basis of the yield obtained, at the rate of $36,000 per million gallons daily. This price included the wells, suction mains and pumping-plant, complete. As the yield of the Baiseleys and Spring Creek stations combined was determined, under test, to be over eight million gallons daily, and the yield of the Forest Stream and Clear Stream stations over 10 million gallons daily, the cost for each station was from $150,000 to $180,000. The pumping-stations consisted of a small brick building, with two pumps and two boilers, the total value of the stations probably not exceeding $30,000, making a very high cost for the well system.

The well plants installed at Spring creek and Watts pond were also contracted for on the basis of the yield, but the price was $5,000 for the first million gallons and $4,000 for each additional million gallons. The resulting cost of the Spring Creek system of wells was about $19,000, while the Watts Pond plant cost about $14,000. These prices did not include any pumping-plants.

The five stations on the new watershed were constructed at a contract price originally fixed at $167,500. The contractors guaranteed a yield of 25 million gallons daily, based on a year's continuous test, during which the yield was to be determined by the minimum average shown for any five consecutive days; and agreed to furnish and run the necessary pumping-plants, with connections to the conduit, and remove the same at the end of the test. As the stations failed to fulfill the contract requirements, the contract was terminated by reducing the payment to about $112,000, which included the pumping-plants installed by the contractor, the discharge mains and all appurtenances, and the operation of the plants for about one year. The payment made was little, if any, in excess of the cost of operation during the test together with the cost of the pumping-plants and appurtenances. The yield of the

five stations, as shown by the test, was slightly under 20 million gallons daily. The land used for the well systems, including ground for the stations and discharge mains, was furnished by The City to the contractors.

The deep wells installed by the Department of Water Supply at Spring creek, Shetucket, Oconee, Jameco and Springfield, cost about $6,000 for each station, including suction main complete. The plants consisted of twelve wells each and the average yield of each station was about three million gallons daily.

In the latter part of 1905 and the early part of 1906, the department installed three shallow well stations, at Aqueduct, St. Albans and Rosedale, at a cost of about $15,000 for each station, complete with frame buildings, pumps and boilers. The work of sinking the wells at these stations was done in part by the department, and the remainder by contractors on a percentage basis. Two of the stations had 20, and one 15 wells. These wells were all six inches in diameter, and were surrounded by a 12-inch cylinder of gravel; they yielded from 2.5 to 4.5 million gallons daily. The cost of the wells complete was about $4 per linear foot, exclusive of suction mains and appurtenances.

In 1906 and 1907 contracts were prepared for sinking deep and shallow wells at various points on the watershed. The prices bid are given in Table 18.

In the bids for sinking wells, received July 25, 1906, the price for the 8-inch pipe included all the labor and material necessary to sink the wells to a depth of approximately 175 feet. The price for the drop suctions included about 30 feet of 6-inch pipe, the T or well head, and a 6-inch valve. All wrought-iron or steel pipe was to be of standard weight. The 6-inch pipe was to be used on top of the strainers in making the joint between the strainer and the casing. The brass strainers were to be 20 feet, and equal to the Johnson or Cook type. The wrought-iron pipe strainers were to be slotted pipe, galvanized, and not covered with gauze.

Under Section II the connections with the gallery called for making a connection with the infiltration gallery, the work involved costing approximately $250 for each connection.

It is evident from the prices bid that the lowest bidder submitted an unbalanced bid.

In the bids received on April 10, 1907, for deep and shallow

TABLE 18

Bids for Sinking Wells, Received by the Department of Water Supply in 1906 and 1907

BIDS FOR DEEP WELLS, RECEIVED JULY 25, 1906

	G. W. Phillips	T. B. Harper	P. H. & J. Conlin
	SECTION I		
6000 feet of 8-inch pipe	$3.07	$3.75	$3.50
30 6-inch drop suctions	0.01	40.00	60.00
200 feet of 6-inch pipe	0.01	0.70	25.00
20 brass strainers	160.00	80.00	118.00
10 wrought-iron pipe strainers	0.01	90.00	120.00
Total bid	**$21,623.00**	**$26,340.00**	**$31,360.00**
	SECTION II		
6000 feet of 8-inch pipe	$3.38	[illegible]	[illegible]
12 6-inch pipe suctions	0.01	[illegible]	[illegible]
600 feet of 6-inch pipe	0.01	[illegible]	[illegible]
18 connections with gallery	0.01	[illegible]	[illegible]
30 brass strainers	160.00	[illegible]	
Total bid	**$25,086.30**	[illegible]	[illegible]
	SECTION III		
4500 feet of 8-inch pipe	$3.07	$3.75	$3.12
25 6-inch drop suctions	0.01	40.00	60.00
260 feet of 6-inch pipe	0.01	0.70	25.00
25 strainers	155.00	80 00	118.00
Total bid	**$17,692.85**	**$20,057.00**	**$24,990.00**

BIDS FOR DEEP AND SHALLOW WELLS, RECEIVED APRIL 10, 1907

	Grant Rohrer	P. H. & J. Conlin	I. Harris Co.
	SECTION I		
8900 feet of 8-inch pipe	$3.63	$4.75	$5.30
40 6-inch suctions	50.00	44.85	48.00
420 feet of 6-inch pipe	2.00	0.92	3.00
40 brass strainers	150.00	85.50	100.00
Total bid	**$41,147 00**	**$47,875.40**	**$54,350.00**
	SECTION II		
6000 feet of 6-inch pipe		$4.25	$4.80
75 6-inch brass strainers		85.50	100.00
75 6-inch well heads		21.90	29.50
Total bid		**$33,555.00**	**$38,512.50**

TABLE 18 (*Concluded*)

BIDS FOR SHALLOW WELLS, RECEIVED APRIL 10, 1907

	I. Harris Co.	McHaig-Barton Co.
SECTION I		
1 steel receiver	$3,077.00	$9,400.00
2000 feet of 8-inch pipe	3.95	6.40
200 feet of 24-inch flanged pipe	0.49	7.00
1500 feet of 16-inch flanged pipe	0.39	0.70
150 feet of 6-inch flanged pipe	0.19	2.50
3 stop-cock chambers	269.00	600.00
Total bid	**$12,495.50**	**$26,825.00**
SECTION II		
1 steel receiver	$3,575.00	$14,350.00
1200 feet of 8-inch pipe	3.95	6.40
60 feet of 30-inch flanged pipe	0.69	15.00
650 " " 16-inch " "	0.39	0.70
450 " " 12-inch " "	0.29	0.60
100 " " 6-inch " "	0.19	2.50
1 stop-cock chamber	120.00	600.00
Total bid	**$8,879.40**	**$24,505.00**
SECTION III		
2000 feet of 8-inch iron or steel pipe	$5.20	
10 suction pipes	48.00	
120 feet of 6-inch iron or steel pipe	2.76	
10 brass strainers	100.00	
Total bid	**$12,211.20**	

Unit prices given in all bids

wells, under Section I the contractor was to sink approximately 40 deep wells, and under Section II approximately 75 shallow wells. The wells under Section I were to be 8-inch wrought-iron pipe wells, sunk to a depth not over 220 feet. The strainers were to be 20 feet in length, with an outside diameter of not less than 5⅝ inches. After the well was sunk the strainer, with a 10-foot piece of 6-inch pipe, was to be placed in the well, the casing drawn to approximately the top of the strainer, and the space between the 6-inch pipe and the 8-inch casing sealed. The drop suctions were to consist of about 30 feet of 6-inch pipe, with a flanged T or well head and a 6-inch stop-cock.

Under Section II the wells were to be sunk to a depth of from 55 to 80 feet by first sinking 12-inch casing, then placing a foot of gravel in the bottom of the casing. On this gravel was to be placed a solid brass strainer about 6 inches in diameter and at least 20 feet long, the well above the strainer being made up of 6-inch wrought-iron pipe. The space between the well and the casing was to be filled with gravel and the casing withdrawn. The well head was to consist of a flanged T, with a 6-inch stop-cock.

On April 10, 1906, bids were also received for shallow and deep wells, the bids being called for in three sections. The wells under Sections I and II were to be shallow 8-inch tile wells, from 48 to 65 feet deep, while under Section III they were to be deep wrought-iron pipe wells.

Under the specifications the tile wells were to be sunk with an 18-inch casing and constructed in a similar manner to the typical well shown on Sheet 51, Acc. L J 187. The City was to furnish the contractor with all the slotted and standard vitrified pipe for the wells, and the pipe and fittings for the drop suctions, but the contractor was to furnish the gravel, 18-inch casing and other appliances necessary to construct the well, and to assemble and place the drop suctions. The flanged suction pipe called for under Sections I and II was to be furnished by The City and laid by the contractor.

Under Section III the contractor was to furnish all his material, the wells to be similar to those called for in the contract previously referred to, for which bids were also received on April 10, 1907. The depth of these wells was to be from 165 to 180 feet.

In the cost of all the wells was included the cost of pumping the wells for from 8 to 24 hours.

The estimated cost of sinking wells, using the department men, without making any allowance for office supervision and general administration, is given in the following table:

ESTIMATED COST OF SINKING WELLS BY EMPLOYEES OF DEPARTMENT OF WATER SUPPLY

Item							
Diameter of wells	2 inches	4 inches	5 inches	6 inches	8 inches	4 inches	8 inches
Type of well	iron pipe	iron pipe	iron pipe	iron pipe	iron pipe	vitrified tile	vitrified tile
Cost per linear foot of well exclusive of strainer							
Material	$0.20	$0.35	$0.45	$0.60	$0.90	$0.22	$0.40
Labor	0.25	0.55	0.60	0.65	0.75	1.60	2.00
Total	**$0.45**	**$0.90**	**$1.05**	**$1.25**	**$1.65**	**$1.82**	**$2.40**
Strainer							
Material	iron pipe brass gauze	brass	brass	brass	brass	slotted tile	slotted tile
Length in feet	5	5–20	5–20	10–20	10–20	20–30	20–30
Cost per foot for							
Material	$0.50	$2.40	$3.10	$4.00	$7.00	$0.30	$0.50
Labor	0.25	0.55	0.60	0.65	0.75	1.60	2.00
Total cost per foot, in place	**$0.75**	**$2.95**	**$3.70**	**$4.65**	**7.75**	**$1.90**	**$2.50**
Cost of well 50 feet deep	$24.00	$65.50	$79.00	$130.50	$204.50	$93.00	$122.50

In 1895 and 1896 a large number of 5-inch test-wells were sunk by the department to determine the stratification at various points along the conduit line. The wells consisted of 5-inch wrought-iron pipe, with a cutting shoe, but no perforated pipe or other form of strainer was used. The cost of the two derricks, with their pumps and other equipment, was about $500 each. The cost of these wells for labor and material is given in the following table:

COST OF SINKING 5-INCH TEST-WELLS, 1895 AND 1896

Well	Depth of Well, Feet	Cost Per Foot: Setting up Machinery	Labor for Sinking Well	Material for Well	Total Cost
1	155	$1.41	$0.44	$0.25	**$2.10**
2	257	0.40	.68	.37	**1.45**
3	277	.32	.37	.31	**1.00**
4	148	.77	1.29	.44	**2.50**
5	284	.42	1.64	.45	**2.51**
6	406	.77	2.04	.76	**3.57**
7	419	.34	.94	.52	**1.80**
8	295	.31	.41	.39	**1.11**
9	271	.29	.72	.44	**1.45**
10	357	.35	.44	.50	**1.29**
11	198	.63	.34	.63	**1.60**
12	406	.23	.69	.40	**1.32**
13	412	.37	.65	.50	**1.52**
14	390	.15	.39	.42	**0.96**
15	190	.41	.44	.49	**1.34**
16	154	.81	.42	.46	**1.69**
17	191	.54	.67	.49	**1.70**
18	192	.42	.35	.44	**1.21**
19	208	.40	.41	.45	**1.26**
20	242	.37	.40	.45	**1.22**
21	410	.20	1.05	.45	**1.70**

Well 6—At 304 feet below the surface the 5-inch pipe broke and the well was continued with a $3\frac{1}{2}$-inch pipe

Well 12—A coupling on the 5-inch pipe broke at 302 feet below surface of ground, and a 3-inch pipe was continued to a depth of 406 feet

Well 13—The 5-inch pipe to 330 feet below the surface; from 330 feet to 404 feet a 3-inch pipe was used; the remainder was drilled without casing off the bore

Well 21—The 5-inch pipe was sunk 398.75 feet and the remainder was drilled

Cost of Water from Driven-Well Stations

The cost of the supply from driven-well stations is dependent upon the fixed charges on the cost of construction, the amount of the supply that can be obtained from a single station, and the cost of operation. With present methods of development, a supply of at least four million gallons daily should be obtained from each driven-well station. The cost of such a supply may be estimated as follows:

Cost of construction		
Land, including grading	$25,000	
Wells, including suction mains	10,000	
Engine and boiler house	15,000	
Pumps, boilers and appurtenances	8,000	
Total		**$58,000**
Land and water damages		50,000
Total		**$108,000**
Annual charges		
Interest, 4 per cent. on $108,000	$4,320	
Taxes, 1 per cent. on $25,000	250	
Sinking fund on bonds, 0.887 per cent. on $108,000	958	
Extraordinary repairs and depreciation	863	
Operation and maintenance	11,479	
Total		**$17.920**
Cost per million gallons		**$12.27**

As compared with this cost, it may be noted that the cost of the supply from the driven-well stations on the old watershed during 1906, exclusive of land and water damages, was $28.92 per million gallons. The greater cost is due to the high first cost of existing plants and the comparatively low yield.

Infiltration Galleries

(See Sheets 52 and 55, Accs. L J 185 and L J 197)

The unsatisfactory results and the large depreciation and repairs on the driven-well systems of the Ridgewood works led to the development of the subsurface supply by means of the infiltration gallery system. Contracts have been made for two infiltration galleries of similar design, with central pumping-stations, the first system, the Wantagh gallery, 12,600 feet long, at Bellmore and Wantagh, and the second, the Massapequa gallery, about 18,200 feet in length, between Seaford and Amityville. Because of the greater length and yield of the Massapequa gallery, larger pipes than those of the Wantagh gallery have been laid to conduct the water to the central well and pumping-station.

The galleries have been constructed in a sheeted trench, excavated from 10 to 15 feet below the normal ground-water level. In this the vitrified tile sewer-pipe is laid on a bed of gravel, leaving the joints of the pipe open and then surrounding them with coarse gravel. A layer of fine gravel is placed over the coarse surrounding the pipes, and the trench is refilled with sand. The lower line of sheeting is usually left in place. These pipes are laid in both directions from the central pump-well and approximately at right angles to the direction of the underground flow. The gradient of the gallery towards the central well is sufficient to carry about double the estimated normal yield of the gallery. To facilitate construction, and also to collect any sand which may enter the gallery, manholes with sumps or sand catchers are placed about every 250 feet. The galleries were designed to carry two million gallons daily per thousand linear feet, although the estimated yield during periods of normal rainfall was only one million gallons daily. The water was pumped from the central well by means of centrifugal pumps.

Plan and profiles, with details of construction of the Wantagh and Massapequa galleries, are shown on Sheet 52, Acc. L J 185. Cast-iron pipe was laid in a portion of the Wantagh gallery, within the village of Wantagh, where the gallery was under a public street. The cast-iron pipe was laid with practically water-tight joints so as to prevent any possible contamination of the supply from future sewerage systems.

In designing these infiltration galleries, they were planned on the basis that construction would be carried on in both directions from the central well, the pumps at the central well station keeping the water-level down, thus reducing the cost of excavation of the trench and laying of the pipe. Upon the completion of one or two sections of the gallery, a bulkhead was to be placed in the end manhole and the water from the gallery allowed to flow to the central well. The Wantagh gallery was constructed in accordance with this general plan. The Massapequa gallery was started from several points, but the contractor abandoned this method owing to the relatively high cost of handling the water, and has continued the work from only those points where a central station could remove the water from the trench. Owing to the necessity for an additional supply, two temporary central stations have been established on the Massapequa gallery in addition to the station provided for in the contract.

The Wantagh gallery was commenced in 1903, but very little work was done prior to the spring of 1905, owing to delay in acquiring the necessary right-of-way. The gallery was completed in the fall of 1906, requiring practically two working seasons after the contractor's plant had been assembled. The rate of progress on this gallery, during the working season, was 109 feet per week for the west branch, and 96 feet for the east branch.

The contract for the Massapequa gallery was let in the summer of 1905, but practically no work was done until 1906. It will probably require about three months' time to complete this gallery, making the entire period, from the letting of the contract to the completion of the same, nearly three years. The rate of progress on this gallery has been much less than that on the Wantagh gallery, the average work done per week for each gang being about 57 linear feet.

Yield of Galleries

Sheet 55, Acc. L J 197, shows the amount of water pumped from the Wantagh gallery during 1905, 1906 and 1907. As this gallery is slightly over 12,000 feet in length, it will be seen that the yield per thousand feet has averaged somewhat above one million gallons daily since the gallery was completed, although this rate would doubtless be reduced if operated continuously.

The Massapequa gallery has not been operated at a sufficiently uniform rate to enable deductions to be made as to what will be the ultimate yield of the works, but it can reasonably be expected that the yield will be proportionately equal to that shown by the Wantagh gallery, where the pumping was carried on for a sufficient period to eliminate the ordinary fluctuations that would be caused by draft on the ground-water storage.

Cost of Infiltration Galleries

The following is a summary of the unit prices of the bids received on June 16, 1903, and July 19, 1905, respectively, for the construction of the Wantagh and Massapequa galleries:

WANTAGH INFILTRATION GALLERY

Item	Estimated Amount	J. J. Cushman, N. Y.	Cont. Jewell Filt. Co.
Earth	700 cubic yards	$0.60	$2.00
Concrete	250 " "	8.00	10.00
Engine and boiler-house	1	3500.00	3500 00
Coal-shed	1	3000.00	3000.00
Pumping-plant	1	5000.00	10,000.00
30-inch suction pipe	150 feet	15.00	12.00
42-inch discharge pipe	150 "	17.00	12.00
Pump-well	1	3600.00	2000.00
36-inch vitrified pipe	2550 feet	13.00	9.00
33 " " "	1070 "	12.00	9.00
30 " " "	2700 "	10.50	8.00
27 " " "	1070 "	9.50	6.50
24 " " "	1600 "	8.00	5.00
20 " " "	1600 "	7.00	4.00
30 " cast-iron flanged pipe	1800 "	15.00	12.50
Hemlock	10 M ft.B.M.	30.00	25.00
Gravel	500 cubic yards	3.00	1.00
Sump boxes	40	90.00	100.00
30-inch foot valves	2	363.00	500.00
Total bid		**$163,951.00**	**$130,285.00**

MASSAPEQUA INFILTRATION GALLERY

Item	Amount	M. J. Dady	Borough Construction Co.
Engine and boiler-house	1	$10,000.00	$9,600.00
Coal-shed	1	7,500.00	6,000.00
Engines	3	20,000.00	17,500.00
Boilers	3	12,000.00	6,000.00
Steam fitting	....	5,000.00	1,700.00
36-inch suction pipe	75 feet	30.00	14.00
48 " delivery pipe	750 "	30.00	18.40
Pump-well	1	10,000.00	5,970.00
36-inch vitrified pipe	8100 feet	10.00	14.00
33 " " " single	1600 "	10.00	14.00
33 " " " double	4300 "	18.00	23.63
30 " " " single	1600 "	10.00	12.58
27 " " " "	550 "	10.00	12.24
24 " " " "	1100 "	10.00	10.56
20 " " " "	1100 "	10.00	9.85
Sump boxes	52	150.00	100.00
" " double	17	200.00	150.00
36-inch foot valves	2	1,000.00	800.00
Wagon road, including bridge	1	5,000.00	750.00
Brick masonry	20 cubic yards	20.00	15.00
Hemlock	10 M ft.B.M.	40.00	25.00
Extra gravel	1000 cubic yards	0.50	1.50
" concrete	100 " "	10.00	10.00
" earth	100 " "	2.00	2.00
Total bid		**$327,850.00**	**$361,690.00**

The difficulty of construction was underestimated when the bids were made for the Wantagh gallery, and the cost of this gallery is said to have been materially in excess of the contract price. Even the prices for the Massapequa gallery were probably too low to allow the contractor a fair profit, under the present system of construction.

Assuming the yield from the galleries to be one million gallons daily per thousand feet, the cost for construction per million gallons daily, based on bid prices, would be as follows:

Wantagh gallery	$10,500
Massapequa gallery	17,800

The cost of a driven-well plant like those of the Ridgewood system, with a similar type of building for the pumping-station, would be about $8,300 per million gallons per day, assuming a yield of four million gallons daily. The cost per million gallons for construction of the gallery is, therefore, about double that for a driven-well system, on the basis of the Massapequa prices. The rate of construction of the galleries, if carried on economically, is moreover exceedingly slow.

Cost of Water from Galleries

The cost of water obtained from the Massapequa gallery, assuming that the total land and water damages would amount to $150,000, would be as follows:

Construction Cost

Land	$150,000
Fencing	20,000
Grading	20,000
Land and water damages	150,000
Galleries	335,000
Pump and boiler-house and coal-shed	20,000
Equipment and pumping	45,000
Total	$740,000

In the above estimate a rather liberal allowance has been made for engineering contingencies in each of the estimates. In the cost of the gallery, allowance has been made for additional cost due to leaving the sheeting in place.

ANNUAL OPERATING EXPENSES

FIXED CHARGES		
Interest 4 per cent. on $740,000	$29,600	
Sinking fund 0.887 per cent. on $740,000	6,564	
Taxes 1 per cent. on $170,000	1,700	
Total		**$37,864**
OPERATING, INCLUDING REPAIRS AND MAINTENANCE		
Salaries	$11,180	
Supplies and minor repairs	1,500	
Coal	5,022	
Total		**$17,702**
EXTRAORDINARY REPAIRS AND DEPRECIATION		
Buildings and fence 3½ per cent. on $40,000	$1,400	
Equipment 3½ per cent. on $45,000	1,575	
Gallery 1½ per cent. on $335,000	5,025	
Total		**$8,000**
Total annual expenses		**$63,566**
The total cost of water per million gallons, assuming that the Massapequa gallery will furnish on an average 17.2 million gallons daily $= \frac{63,566}{6,279}$		**$10.12**

This cost of water per million gallons is evidently much lower than the average cost of water obtained from the driven-well stations on the watershed.

Influence of Collecting Works on Underground and Surface-Water Levels

Sheets 53, 54 and 57, Accs. L J 196, L J 223 and L J 225, show the effect of the operation of the infiltration galleries and wells at Wantagh and at Massapequa on the levels of the surface and ground-waters. (See also Sheet 151, Acc. L 644).

It will be seen that there is a decided depression of the water-table in the immediate vicinity of the wells and galleries, and that the amount of this lowering decreases rapidly as the distance increases south or north of the collecting works. The lowering of the water-table near the infiltration galleries results in the drying up of the ponds and the small streams south of the galleries, and in a reduced flow of the larger streams that enter the brick conduit as a part of the surface supply.

Amount of Ground-Water Storage

The number of observations of the ground-water surface about the works of the Ridgewood system is not sufficient to compute accurately the amount of storage that these ground works are able to draw, but a rough approximation may be made at several stations.

Sheet 56, Acc. LJ 193 shows the depth of pumping at the driven-well stations, below the normal ground-water surface, corresponding to the total daily yield of the stations, corrected roughly for storage draft. These depths were measured in test-wells driven close to the service wells. Except in two instances, these curves have a point of inflection beyond which any further lowering of the water-table does not yield a corresponding volume of water. This critical depth is found from 8 to 12 feet below the normal surface of the ground-water and doubtless corresponds to the depression at which the finer strata in the gathering ground seriously interfere with the further extension of the cone of depression. A station like Jameco (deep wells) which draws upon beds of coarse gravels extending back into the watershed, has not this limitation on the extent of gathering ground and the curve on this diagram is very nearly a straight line.

The observations at the Clear Stream driven-well station in 1906 (See Sheet 57, Acc. LJ 225) show that in about 100 days of pumping, from April 23 to August 6, the ground-water surface was depressed for about one mile north of the works. During this time, 223.6 million gallons of water were pumped, at an average rate, when pumping, of 3.1 million gallons daily. Rough estimates show that about 80 million gallons of storage were drawn, assuming the somewhat fine material there would yield 20 per cent. of their volume in this time.

The ground-water surface at the station was lowered 13 feet, which represents about the maximum lowering that is possible, with the equipment there. If pumping were continued, therefore, the amount of storage in the following three months would not be as much as that from April 23 to August 6. Of the volume of water pumped during this period something over one-third was storage. If the plant had been operated continuously until April, 1907, it is very likely that the storage draft would not have been over one-tenth of the total pumpage. If 100 million gallons of storage could be drawn at this station, it would correspond to something like 25 million gallons per square mile on the catchment area.

The influence of pumping at the Wantagh infiltration gallery from December, 1905, to December, 1906, is shown on Sheet 57, Acc. LJ 225, to have extended some distance inland, but the amount of depression was not appreciable much over a mile north of the works, and not enough at a distance of ½ mile to be noticeable to an unskilled observer. The average yield of the gallery during this year of operation, shown on Sheet 55, Acc. LJ 197, was one million gallons per day per 1000 feet of gallery, and the storage drawn per 1000 feet of gallery, supposing 20 per cent. of the saturated strata were drained out, is estimated at 24 million gallons, which corresponds roughly to 14 million gallons per square mile of tributary watershed of 1.7 square miles. This storage is evidently less than seven per cent. of the average yield during the year. The lowering of water at the gallery during the year was about nine feet.

The amount of ground-water storage that the Ridgewood works can furnish may be roughly estimated at 20 million gallons per square mile, and does not greatly affect the rate of draft from the watershed. With the 9.4 million gallons

per square mile of storage in surface storage, the total storage does not exceed 30 million gallons per square mile.

TRANSPORTATION WORKS

The transportation works comprise the combined gravity and pumping system by which the waters collected in the watershed are conveyed to New York City.

Conduits

The waters gathered east of the Millburn pumping-station are delivered through a brick conduit having a grade of 1 in 10,000. At its easterly end, at Massapequa, this conduit, the "new brick conduit," so called, has a horse-shoe section, 5 feet 11 inches high and 7 feet 4 inches wide and has a capacity of 40 million gallons daily. The size increases at each supply pond, and at its downstream or westerly end at Millburn pumping-station the section is 6 feet 11 inches high by 9 feet 4 inches wide and has a capacity of 60 million gallons daily.

From the Millburn station the water delivered by this brick conduit is pumped through three 48-inch cast-iron pipe-lines. One of these goes to the efflux gate-house of the Millburn reservoir, where it is reduced to a 36-inch cast-iron pipe, which continues to the old brick conduit at Smiths pond. The other two 48-inch lines extend directly to the Ridgewood pumping-station, the northerly line being reinforced by an additional 48-inch main between Spring creek and Ridgewood.

The original brick conduit in the old watershed transports the surface and ground-waters collected from Hempstead pond to Ridgewood pumping-station. It has a horse-shoe section 6 feet 4 inches by 8 feet 2 inches at Hempstead pond, and increases to 8 feet 8 inches by 10 feet at Ridgewood. The capacity of this conduit, the invert of which has a grade of 1 in 10,411, is 40 million gallons daily at its easterly end and 75 million gallons daily at the down-stream end at Ridgewood pumping-station. Branch conduits of brick masonry connect this main aqueduct with the various supply ponds.

A 72-inch steel-pipe line, designed to be operated under the full distribution pressure, has been laid from a point about 3000 feet west of the Ridgewood station to the Clear Stream pumping-station. A 48-inch main connects this 72-inch line with the Ridgewood pumping-station and a 20-inch branch line has been laid to the New Lots station.

The Water Department proposes to extend the 72-inch steel pipe, full size, to the Suffolk County line. It is proposed to utilize this line to convey the water from the infiltration galleries and other sources in the new watershed, and it is planned that pumps would be installed at Massapequa and Wantagh to deliver the water directly through this conduit into the distribution system. The extension of this 72-inch line to Massapequa would relieve both the old and new brick conduits of approximately 30 to 50 million gallons daily.

The capacities of the main conduits and their relation to the available supply are shown in the mass curves on Sheet 2, Acc. LJ 147.

Pumping-Stations

On account of the low elevation at which the water-supply from the Ridgewood system is collected, it is necessary at the westerly end of the conduit lines at the Ridgewood station to pump the entire supply to the elevation of the distributing reservoir.

About 90 per cent. of the whole supply is raised at the Ridgewood pumping-station to the level of the Ridgewood reservoir on the hill north of the station; the remaining 10 per cent. is pumped to the level of Mt. Prospect reservoir, which is at a higher elevation on the hills about five miles west of the station. A portion of the Ridgewood Reservoir supply is again raised at the Mt. Prospect pumping-station, near the reservoir of the same name, into the Mt. Prospect tower, which serves a district still higher than that supplied by the reservoir. The Mt. Prospect pumping-station is also equipped to deliver water into the Mt. Prospect reservoir, but the greater part of the water for this reservoir is pumped directly from the Ridgewood station.

A portion of the Ridgewood supply is even lifted once or twice in the watershed before it reaches Ridgewood. The entire supply from the new watershed is pumped at the Millburn pumping-station; all the ground-waters of both watersheds are pumped into the conduits and the surface-waters of Baiseleys, Springfield, Watts and Smiths ponds, and the flow of Simonsons stream in the old watershed are pumped into the old brick conduit. The remainder of the surface supplies enter the brick conduits by gravity.

MILLBURN PUMPING-STATION

At the Millburn station the water is raised about 50 feet, thus giving the necessary pressure to deliver the required supply at the Ridgewood station either through the two cast-iron conduits or through the pipe-line between this station and the old brick conduit at Smiths pond, which is seven feet higher than the new brick conduit at Millburn pumping-station. The engine equipment consists of five pumps, each of 10 million gallons daily capacity, and two pumps each of 12½ million gallons daily capacity. The first five pumps are designed for a maximum pressure of approximately 16 pounds per square inch, while the larger pumps are designed to work against a head of 25 pounds per square inch.

As the pumps at this station can deliver 20 per cent. more than their rated capacity, or about 90 million gallons daily, the safe pumping capacity of the station is about 75 million gallons daily. This is in excess of the capacity of the brick conduit feeding the station, which is only 60 million gallons daily. Under the present plans of the department, there will be no necessity for additional pumping capacity at this station, as the increase in the supply from Wantagh and Massapequa galleries will be pumped through the 72-inch steel-pipe line against the distribution pressure, and thus reduce the amount of water delivered at the Millburn station.

RIDGEWOOD PUMPING-STATION

The station at Ridgewood is the main pumping-station of the system. The station is divided into two plants; one on the north side of Atlantic avenue is known as the "Ridgewood Old pumping-station," and the other on the south side is called the "Ridgewood New pumping-station." The northerly plant was constructed at the time the first works were built; the southerly plant formed a part of the extension of the works into the new watershed, and was built in 1890. The north side station is at present being remodeled, and one of the pumps, which was installed in 1867, is to be taken out and four new pumps erected.

The present and future equipment of the Ridgewood pumping-station is as follows:

	Capacity in Million Gallons Daily
North Side Station	
Present Equipment	
1 Davidson pump	15
3 Worthington pumps, each 20 million gallons daily.	60
1 Hubbard and Whittaker	15
Total	90
Equipment after Remodeling	
1 Davidson pump	15
3 Worthington pumps, each 20 million gallons daily.	60
2 Davis and Farnum pumps, each 23 million gallons daily	46
2 Davis and Farnum pumps, each 15 million gallons daily	30
Total	151
South Side Station	
Present Equipment	
5 Worthington pumps, each 10 million gallons daily.	50
1 Lawrence centrifugal	*20
Total	70

*Capacity provided in contract. Pump not yet accepted

As the work of remodeling the North Side station is all under contract, the new equipment should be available in 1909. The proposed method of operating the station, and the available safe capacity after the remodeling is completed, is as follows:

The North Side station is designed to pump against the Mt. Prospect Tower service at an elevation of about 280 feet, the Mt. Prospect Reservoir service at an elevation of about 210 feet, and the Ridgewood service at an elevation of about 180 feet. The elevations given include the normal

friction losses in the force mains between the pumps and the reservoirs.

The two new 15-million-gallon pumps are designed to pump into the Mt. Prospect tower. This service requires at present about seven million gallons daily, but the consumption is rapidly increasing. Owing to the small storage capacity of the tower, 119,000 gallons, it is necessary to have pumping capacity sufficient to meet the hourly fluctuations in the consumption. One of the pumps would be kept in constant service, and the other pump maintained as a reserve.

For the Mt. Prospect Reservoir service, there is available at present the Davidson pump, the consumption on this service being about 10 million gallons daily. The two new 23-million-gallon pumps are designed to be used either for this service or for the Ridgewood Reservoir service. To safely and economically maintain the Mt. Prospect Reservoir service, one of the 23-million-gallon pumps should be used and the Davidson pump held in reserve.

For the Ridgewood Reservoir service, there would be available the three 20-million-gallon Worthington pumps and one of the new 23-million-gallon Davis and Farnum pumps, although there would not then be any reserve pump for this service.

On the above basis, the available safe capacity of the North Side station would be as follows:

Mt. Prospect Tower service.......	15	million	gallons	daily
Mt. Prospect Reservoir service....	15	"	"	"
Ridgewood Reservoir service......	83	"	"	"
Total	113	"	"	"

The South Side station is designed to pump against the Ridgewood Reservoir head. The five Worthington pumps are from 15 to 17 years old and are not strong machines, being frequently in need of repairs. The 20-million-gallon centrifugal pump is a new machine, and it should be possible to operate it almost continuously. It would not be safe, however, to estimate the capacity of this station above 50 million gallons daily.

The total safe capacity of the two stations would be as follows:

North Side station	113	million gallons daily
South Side station	50	" " "
Total	163	" " "

To obtain the above capacity, it would be necessary to allow the surplus water delivered by the Mt. Prospect Tower and Reservoir pumps to discharge into the Ridgewood system. Under normal economical operation, the capacity of the Ridgewood station would be about 155 million gallons daily.

The total capacity of the conduits feeding the Ridgewood station is now 125 million gallons daily, exclusive of the 48-inch pipe from the end of the 72-inch steel pipe. The safe pumping capacity at this station, after remodeling, will therefore be 30 million gallons daily in excess of the conduit capacity.

MT. PROSPECT PUMPING-STATION

This station has two pumps of a total capacity of nine million gallons daily for the Reservoir service, and three pumps of a total capacity of 13 million gallons daily for the Tower service. These pumps draw their supply from the distribution mains of the Ridgewood Reservoir service, and may be abandoned when the new pumps are completed at Ridgewood and the necessary additional force mains are installed.

The plans of the Department of Water Supply include new pumping-plants for the Massapequa and Wantagh infiltration gallery stations, in connection with the proposed extension of the 72-inch pipe-line. These plants would consist of high-duty pumps with a combined capacity of 50 million gallons daily, capable of delivering the water into the distribution system against the head of the Ridgewood Reservoir service.

The combined safe pumping capacities of the Ridgewood pumping-station and the two new stations proposed at Wantagh and Massapequa, when these stations are completed in accordance with the plans of the Department of Water Supply, would be 205 million gallons daily, which is greater than the total yield of the entire system when completely developed.

DISTRIBUTION SYSTEM

Reservoirs

The distribution system of the Brooklyn municipal supply is divided into three levels. The highest is that of the Mt. Prospect tower or stand-pipe, the flow line of which is at an elevation of 280 feet; the intermediate service is supplied from the level of the Mt. Prospect reservoir, which has a normal high-water line of 200 feet; the low level, which includes 85 per cent. of the supply, is fed from the Ridgewood reservoir, which has a high-water line at an elevation of 172 feet. These elevations refer to the datum of the Board of Water Supply.

The Ridgewood reservoir is divided into three independent basins, and is provided with a 60-inch steel by-pass pipe through which the water can pass from the force mains around the reservoir directly into the efflux pipes. The Mt. Prospect reservoir and the three Ridgewood basins are uncovered, and are constructed with earth embankments lined with clay puddle and with the side slopes protected by masonry.

The following table gives elevations, areas and capacities of the stand-pipe and the reservoirs:

Reservoirs	Elevation in Feet on B. W. S. Datum			Area at Normal High-Water Line Acres	Capacity at Normal High-Water Line Million Gallons
	Normal High Water	Top of Bank	Bottom		
Mt. Prospect stand-pipe....	280.0	281.1	205.7	16-feet diameter	0.12
" " reservoir......	200.3	201.5	180.0	3.31	19.2
Ridgewood Reservoir basin, 1	171.9	175.7	151.9	11.85	71.5
" " " 2	171.9	175.7	151.9	13.73	83.0
" " " 3	172.6	176.6	152.6	24.49	149.5
Total	....	....	....	....	**323.3**

A small reservoir was originally constructed in connection with the New Lots system, but this reservoir was abandoned in 1906.

Distributing Mains

The main feeders from Ridgewood reservoir consist of 48-inch and 36-inch mains. There are four 48-inch mains and two 36-inch mains which connect with the smaller distribution mains. In addition there is one 48-inch main laid directly from the Ridgewood pumping-station to the Mt. Prospect res-

ervoir. A 30-inch and a 24-inch branch main supplies the Mt. Prospect pumping-station, and a 20 and a 30-inch force main leads from this pumping-station to the tower and reservoir, respectively.

The standard thickness of the various sizes of pipe and safe working pressure, based on the Metropolitan Water Works formula, are as follows:

Size of Pipe Inches	Thickness Inches	Safe Working Pressure Pounds per Square Inch
48	$1\frac{5}{16}$	76
36	$1\frac{1}{8}$	85
30	1	85
24	$\frac{27}{32}$	78
20	$\frac{3}{4}$	75
16	$\frac{11}{16}$	80
12	$\frac{5}{8}$	96
8	$\frac{17}{32}$	112
6	$\frac{1}{2}$	155

The following table gives the length of mains, number of gates and hydrants in the distribution system on December 31, 1907:

DISTRIBUTION MAINS LAID AND GATES AND HYDRANTS SET, UP TO DECEMBER 31, 1907

Diameter Inches	Mains Laid Miles	Gates Set
60	0.7	....
54	....	1
48	28.0	20
42	0.7	1
36	14.0	42
30	13.0	75
24	7.3	69
20	57.6	507
16	25.1	273
14	0.6	1
12	90.3	996
10	3.7	8
8	209.1	2,816
6	388.2	7,017
4	10.5	101
Total..................	**848.8**	**11,927**
Total hydrants.........	11,814	

OTHER BROOKLYN WORKS

The Flatbush, Blythebourne and German-American stations within the limits of Brooklyn borough, which are owned and operated by private companies, draw their supply of

ground-water from driven wells and pump directly into the distribution system. Stand-pipes and elevated tanks are used to equalize the pressure in the mains and rate of pumping. These works have been constructed in much the same manner as the driven-well stations of the Ridgewood system, and merit no special description. As the population becomes more dense upon their watersheds, the supplies now furnished by these stations must be secured from other sources.

Table 19 gives all the stations utilized for the supply of the Borough of Brooklyn, with date of construction, source of supply, equipment and estimated amount of water pumped daily.

YIELD OF RIDGEWOOD SYSTEM AND QUALITY OF SUPPLY

The extent of development of the Ridgewood system is shown in the main report, pages 55 to 102. The yield of the surface and ground-water collecting works are given in the main report, and in Appendix 1, pages 103 to 133, in connection with a discussion of the safe yield of the proposed ground-water collecting works in Suffolk county.

The quality of the waters of the Ridgewood system is presented in Appendix 2, pages 134 to 166, where a comparison is made with typical surface and ground-water supplies in large cities in this country and abroad.

COST OF THE RIDGEWOOD SYSTEM

Construction

To determine the cost of the Ridgewood system, it has been necessary to compile the data given in the annual reports of the Water Department and of the Comptroller, and, in addition, the cost so well presented in the History of the Brooklyn Water Works, 1896. While the cost has been determined as accurately as the data available would permit, there are probably some slight errors, which, however, are not large enough, if they exist, to materially affect the resulting cost of the water.

Table 20 gives a summary of the cost of the works up to January 1, 1907, and the cost of operation and maintenance including interest and sinking fund charges. In estimating the cost of the works deductions have been made for worn out

TABLE 19

NAME OF STATION	DATE OF CONSTRUCTION OF STATION	SOURCE OF SUPPLY	NORMAL AMOUNT PUMPED M.G.D.	TOTAL LIFT IN FEET	NUMBER	DATE OF INSTALLATION	ENGINE EQUIPMENT TYPE	NOMINAL CAPACITY M.G.D.
RIDGEWOOD SYSTEM								
Mt Prospect	1862	Ridgewood	2.0	70	1	1890	Vertical Comp Beam & Fly Wheel Wright	5.0
Mt Prospect		Reservoir			1	1886	Vertical Simple " " " Wright	4.0
Mt Prospect	1893	Distribution Mains	6.0	165	2	1894	Horiz Direct Triple Davidson	2.5
Mt Prospect					1	1898	Horiz Direct Triple Davidson	3.0
Mt Prospect					1	1905	Two stage Center geared to St'm Turb. De Laval	6.0
Ridgewood N.S.	1858	Surface Streams and Ground Waters between Massapequa and Ridgewood	80.	182	1	1867	Vertical Beam & Fly wheel Hubbard & Whittaker	15.0
Ridgewood N.S.	1858				2	1883	Vertical Direct Acting Duplex Davidson	7.5
Ridgewood N.S.	1883				3	1896	Vertical Triple Expansion Worthington	20.0
Ridgewood S.S.	1890		40.	168	3	1890	Vertical Compound Worthington	10.0
Ridgewood S.S.	1890				2	1893	Vertical Compound Worthington	10.0
Ridgewood S.S.	1906				1	1906	Triple Expan. Centrifugal Lawrence	20.0
Spring Creek	1883	Driven Wells	6.0	36	2	1883	Horiz Direct Acting Duplex Comp'd. Knowles	3.0
Spring Creek	1896	Driven Wells			1	1896	Horiz Direct Acting Comp'd. Davidson	5.0
Woodhaven	1907	Driven Wells	4.0	55	1	1907	Horiz Direct Acting Comp'd. Worthington	3.5
Aqueduct	1906	Driven Wells	4.0	55	2	1906	Direct Connect Centrifugal Pumps Morris	3.0
Shetucket	1907	Driven Wells	3.0	35	1 1	1907	Horiz Direct Acting Comp'd Worthington Direct Connect Cent'g'l Donegan & Swift.	3.5 3.0
Oconee	1898	Driven Wells	3.5	35	1	1898	Horizontal Direct Acting Davidson	5.0
Morris Park	1907	Driven Wells	4.0	35	1	1907	Horiz Direct Acting Comp'd Worth'gton	5.0
Baiseleys	1883	Driven Wells	2.0	36	2	1883	Horiz Direct Comp'd. Duplex Knowles	3.0
Jameco	1888	Baiseleys Pond and Driven Wells	8.0	32	1	1890	Horiz Direct Triple Expan. Davidson	5.0
Jameco	1888				1	1890	Horiz Direct Comp'd Duplex Worthington	6.0
Jameco	1888				1	1891	Vertical Crank & Fly Wheel Andrews	5.0
Jameco	1888			20	1	1901	Direct Connect. Centrifugal Lawrence	6.0
St. Albans	1906	Driven Wells	3.0	35	1	1906	Horiz. Direct Acting Davidson	3.0
St. Albans	1906	Driven Wells			2	1906	Direct Connect Centrifugal Donegan & Swift	3.0
Springfield	1884	Driven Wells	3.0	29	1	1882	Horiz Direct Comp. Duplex Davidson	3.0
Springfield	1881	Pond	1.0	22	1	1901	Direct Connected Centrifugal Lawrence	5.0
Rosedale	1906	Driven Wells	3.0	35	2	1906	Direct Connect. Cent'g'l Buffalo Forge Co	3.0
Forest Stream	1885	Driven Wells	6.0	35	2	1885	Horiz. Direct Cross Comp'd Cr. & F. Wh'l Knowles	5.0
Clear Stream	1885	Driven Wells	3.0	37	2	1885	Horiz Direct Cross Comp'd Cr. & F. Wheel Knowles	5.0
Watts Pond	1881	Watts Pond & Driven Wells	3.0	30	1	1885	Horiz Direct Comp'd Duplex Worthington	3.0
Smith Pond	1873	Smith Pond	100	16	2	1883 1890	Horiz Direct Comp'd Duplex Davidson	5.0
Millburn	1891	Sur. Str. & Gr. Water, Mill-burn to Massap'a	60.	59	5	1892 1893	Horiz Direct Triple Expansion Davidson	10.0
Millburn	1891				2	1903	Horiz Direct Triple Expansion Worth'gton	12.5
Agawam	1896	Driven Wells	3.0	36	2	1896	Belt Connected Centrifugal Edwards	5.0
Merrick	1896	Driven Wells	4.0	36	2	1896	Belt Connected Centrifugal Edwards	5.0
Merrick	1896	Driven Wells			1	1896	Horizontal Direct Worthington	2.0
Matawa	1896	Driven Wells	2.5	32	2	1896	Belt Connected Centrifugal Edwards	5.0
Wantagh	1896	Driven Wells	3.0	32	2	1896	Belt Connected Centrifugal Edwards	5.0
Wantagh	1896	Driven Wells			1	1896	Horizontal Direct Worthington	2.0
Wantagh Gallery	1903	Gallery	12.	20	3	1906	Direct Connected Cent'g'l	8.0
Seaford	1906	Mass. Gall'y	3.5	20	1	1906	Horizontal Direct Worthington	3.0
Seaford	1906	Mass. Gall'y			1	1906	Horizontal Direct Snow	2.0
Massapequa	1896	Driven Wells	2.5	35	2	1896	Belt Connected Centrifugal Edwards	5.0
Massapequa	1896	Driven Wells			1	1896	Horizontal Direct Worthington	2.0
Massapequa Gallery	1906	Gallery	10.0	20	3	1906	Direct Connect. Cent'g'l Allis Chalmer	10.0

NAME OF STATION	DATE OF CONSTRUCTION OF STATION	SOURCE OF SUPPLY	NORMAL AMOUNT PUMPED M.G.D.	TOTAL LIFT IN FEET	NUMBER	DATE OF INSTALLATION	ENGINE EQUIPMENT TYPE	NOMINAL CAPACITY M.G.D.
BOROUGH STATIONS								
New Lots (old)	1881	Driven Wells	2.0	200	1	1883	Horiz. Single acting Davidson	2.0
New Lots (old)	1881	Driven Wells			1	1896	Horiz. Direct acting Worthington	2.0
New Lots (new)	1906	Driven Wells	4.0		2	1906	Horiz. Triple Exp. Cr. & Fly Wh'l Groshon	5.0
Gravesend (old)	1892	Driven Wells	3.0	170	1	1892	Horiz. Comp'd Duplex Deane	5.0
Gravesend (old)	1892	Driven Wells			1	1892	Horiz. Comp'd Duplex Worthington	2.0
Gravesend (new)	1906	Driven Wells			1	1906	Horiz Triple Exp. Cr. & Fly Wh'l Snow	6.0
New Utrecht	1885	Driven Wells	1.5	180	1	1885	Horiz Comp'd. Duplex Worthington	2.0
New Utrecht	1885	Driven Wells			1	1885	Horiz. Duplex Knowles	1.5
PRIVATE COMPANIES								
Flatbush (old)	1884	Driven Wells	7.0	180	1	1884	Horiz. Comp'd Duplex Worthington	3.0
Flatbush (old)	1884	Driven Wells			1	1884	Horiz Comp'd Duplex Knowles	2.5
Flatbush (old)	1884	Driven Wells			1	1893	Horiz. Comp'd Duplex Worthington	1.0
Flatbush (old)	1884	Driven Wells			1	1899	Horiz. Comp'd Duplex Worthington	7.0
Flatbush (new)	1905	Driven Wells			1	1905	Horiz. Triple Exp. Duplex Worthington	8.0
Blythebourne	1891	Driven Wells	1.5	150	1	1900	Horiz Comp'd Duplex Worthington	1.5
Blythebourne		Driven Wells			1	1906	Horiz. Comp'd Duplex Worthington	2.5
German Amer.		Driven Wells	.5		1	1891	Horiz Comp'd Duplex Worthington	0.35
German Amer.	1891	Driven Wells			1	1905	Horiz Comp'd Duplex Worthington	0.35
German Amer.		Driven Wells			1	1907	Horiz Comp'd Duplex Worthington	0.35

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
EQUIPMENT OF PUMPING STATIONS
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and abandoned equipment. The total cost has been subdivided into works for collection, transportation, pumping and distribution. The annual charges are based on the recorded expenditures for operation and maintenance during 1906, and to this has been added interest on the total estimated cost to date of works at present in use, and estimated extraordinary repairs and depreciation on these works, based on their probable life.

Annual Charges

The cost of the water per million gallons supplied during the year 1906 has been estimated in Table 21, on the basis of the annual charges given in Table 20. The cost of collection has been subdivided into ground-waters and surface-waters. The cost of transportation has also been divided into the cost of transporting the water from the new watershed to Millburn pumping-station, and then transporting this water through the pipe-lines from the Millburn pumping-station to the Millburn reservoir and Smiths pond. It was assumed that 45 million gallons daily of the supply from the new watershed would go through the two 48-inch pipes and the proposed 72-inch steel-pipe line, and the cost of transportation has been based upon the charges on the cost of these lines. The cost for transporting the remainder of the supply from the new watershed through the brick conduit in the old watershed is based on the charges on the cost of this conduit, allowing for the supply from the new watershed a proportional part of the total volume of water carried in this aqueduct, which in 1906 amounted to 58 million gallons daily from the old watershed and 14 million gallons daily from the new.

In determining the cost of distribution and collection of water rates, the entire supply furnished both by the Ridgewood system and by the driven-well stations outside of this system, in the borough limits, has been taken. The cost of water thus determined is not the actual cost at the present time, as the estimates have been made on a basis similar to that used for the estimates of cost of water from proposed works in Suffolk county and are, therefore, comparable with them.

To determine the actual cost of water to the consumer, the total annual expenditures made for interest on bonds and maintenance of works, including the collection of the revenue, have been taken, from 1901 to 1906, and to these has been

TABLE 20

Cost of Construction, Annual Charges, and Cost per Million Gallons for Brooklyn System

From Amityville To	Total Amount Supplied During 1906 in Million Gallons	Average Daily Supply in Million Gallons	Cost of Construction of Brooklyn System: Ridgewood System: Collection	Ridgewood System: Transportation	Ridgewood System: Total Transportation and Collection	Distribution System	City Stations	Total Cost of Brooklyn System
Millburn	21,594	59.16	$1,748,000	$1,225,000	$2,973,000	....	....	....
Through Millburn pumps	21,594	59.16	1,748,000	1,718,000	3,467,000	....	....	....
Millburn reservoir	21,594	59.16	2,788,000	1,967,000	4,755,000	....	....	....
Ridgewood pumping-station	42,718	117.03	6,734,000	6,258,000	12,992,000	....	....	....
Through Ridgewood pumps	42,718	117.03	6,734,000	7,684,000	14,418,000	....	....	....
Distribution reservoirs	42,718	117.03	6,734,000	10,166,000	16,900,000	....	....	$16,900,000
Distribution system	46,380	127.07	....	....	....	$12,497,000	....	12,497,000
Water register	46,380	127.07	....	....	....	....	$700,000	700,000
Totals	**46,380**	**127.07**	**$6,734,000**	**$10,166,000**	**$16,900,000**	**$12,497,000**	**$700,000**	**$30,097,000**

From Amityville To	Annual Charges, Interest, Sinking Fund, Extraordinary Repairs and Depreciation, Taxes and Operating Expenses: Collection	Transportation	Total Transportation and Collection	Distribution and Water Rates	Total	Cost per Million Gallons, Interest, Sinking Fund, Extraordinary Repairs and Depreciation, Taxes and Operating Expenses: Collection	Transportation	Distribution and Water Rates	Total
Millburn	$304,300	$63,300	$367,600	....	$367,600	$14.09	$2.93	.....	$17.02
Through Millburn pumps	304,300	184,100	488,400	....	488,400	14.09	8.53	.....	22.62
Millburn reservoir	355,100	196,200	551,300	....	551,300	16.45	9.09	.....	25.54
Ridgewood pumping-station	932,500	409,800	1,342,400	....	1,342,400	21.83	9.59	.....	31.42
Through Ridgewood pumps	932,500	1,019,100	1,951,600	....	1,951,600	21.83	23.86	.....	45.69
Distribution reservoirs	932,500	1,215,800	2,148,300	....	2,148,300	21.83	28.46	.....	50.29
Distribution system	....	....	....	$982,353	3,130,604	.....	.....	$21.18	71.47
Water register	....	....	....	85,422	3,216,026	.....	.....	1.84	73.31
Totals	**$932,500**	**$1,215,800**	**$2,148,300**	**$1,067,800**	**$3,216,100**	**$21.83**	**$28.46**	**$23.02**	**$73.31**

Cost of Construction, An[illegible]

From Amityville To	Total Amount Supplied During 1906 in Million Gallons	Average Daily Supply in Million Gallons	Cost of Con[illegible] — Ridgewood System — Collection	Transportation	Tot[illegible] port[illegible] Co[illegible]
Millburn	21,594	59.16	$1,748,000	$1,225,000	$2[illegible]73
Through Millburn pumps	21,594	59.16	1,748,000	1,718,000	3[illegible]67
Millburn reservoir	21,594	59.16	2,788,000	1,967,000	4[illegible]55
Ridgewood pumping-station	42,718	117.03	6,734,000	6,258,000	12[illegible]92
Through Ridgewood pumps	42,718	117.03	6,734,000	7,684,000	14[illegible]18
Distribution reservoirs	42,718	117.03	6,734,000	10,166,000	16[illegible]00
Distribution system	46,380	127.07	....	....	...
Water register	46,380	127.07	....	....	...
Totals	**46,380**	**127.07**	**$6,734,000**	**$10,166,000**	**$16[illegible]00**

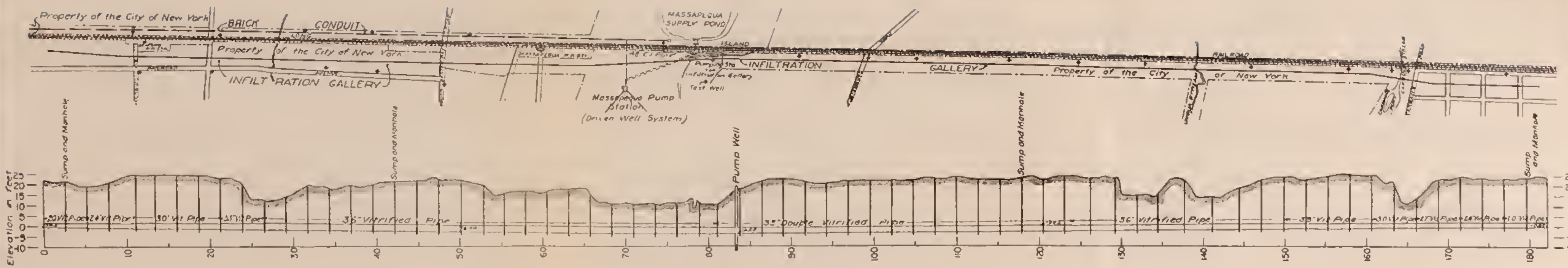
TABLE 21

Cost of Water per Million Gallons from Brooklyn System in 1906, Based on Assumed Life of Works and Total Cost of Construction of Works in Use

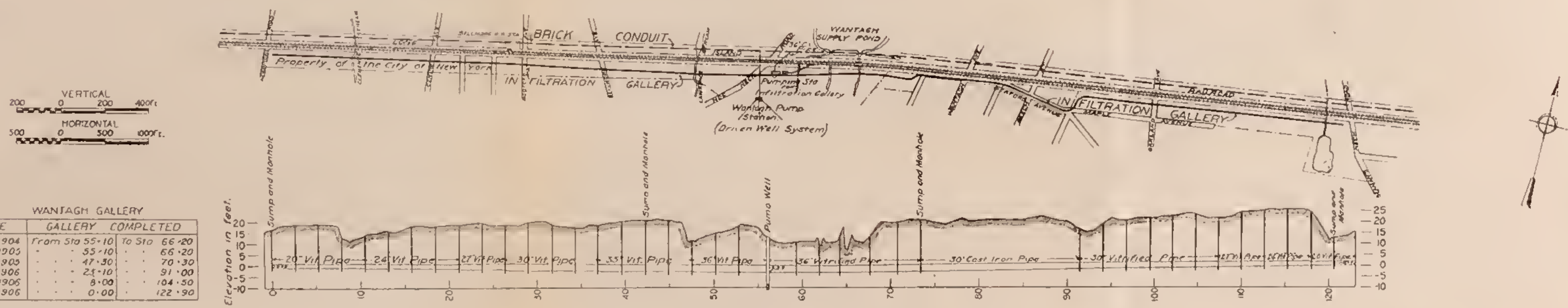
	Quantity of Water Delivered in 1906 Million Gallons	Collection Average Charges			Through Brick Conduit	Through 48-inch Pipe-lines	Transportation Average Charges: Including 72-inch Pipe-line	Transportation Average Charges: Shed	Transportation Average Charges: Ridgewood System	Pumping	City Distribution	Increment Charges: Collection	Increment Charges: Transportation	Increment Charges, New Watershed: Fixed	New Watershed: Extra—Repairs and Depreciation	New Watershed: Maintenance and Operation	New Watershed: Total	Increment Charges, Old Watershed: Fixed	Old Watershed: Extra Repairs and Depreciation	Old Watershed: Maintenance and Operation	Old Watershed: Total	Ridgewood System
New watershed: Ground-water	11,804	$17.69																				
New watershed: General supplies	21,594		$14.09		$2.93			$2.93				$14.09	$2.93	$7.43	$0.11	$9.48	$17.02					$17.02
New watershed: Surface streams	9,790	9.76																				
				$21.83					$3.00													
Millburn pumping-station	21,594									$5.60				1.21	0.50	3.89	5.60					5.60*
Millburn reservoir	21,594		2.36			$0.56**		.56				2.36	.56	2.92			2.92					2.92
Old watershed: Ground-water	14,284	28.92																$9.64	$0.33	$17.36	$27.33	
Old watershed: General supplies	21,124		27.33		3.91	5.46*	$6.00*	5.00				5.38	.59	5.95		.05	6.00	3.88		.06	3.94	5.88
Old watershed: Surface streams	6,840	21.03																				
Totals										$5.60		$21.83	$3.99	$17.51	$0.61	$13.42	$31.54	$13.52	$0.33	$17.42	$31.27	$31.42
Ridgewood pumping-station	42,718									14.27				1.64	0.75	11.88	14.27	1.64	0.75	11.88	14.27	14.27
Force mains and distribution reservoirs	42,718								4.00				4.00	2.84	0.09	1.67	4.60	2.84	0.09	1.67	4.60	4.00
Distribution system	46,380										$21.18			13.17		8.01	21.18	13.17		8.01	21.18	21.18
Water tax collection	16,380										1.84					1.84	1.84			1.84	1.84	1.84
Grand totals										$19.87	$23.02	$21.83	$8.59	$35.16	$1.45	$36.82	$73.43	$31.17	$1.17	$40.82	$73.16	$73.31

*These charges are for water from the new watershed passing through the 48-inch pipes, built on the old watershed. The 72-inch steel-pipe line is not completed, but charges have been included for the portion completed in 1906

**This charge is for transporting water through the 48-inch pipe-line from Millburn pumping-station to Millburn reservoir



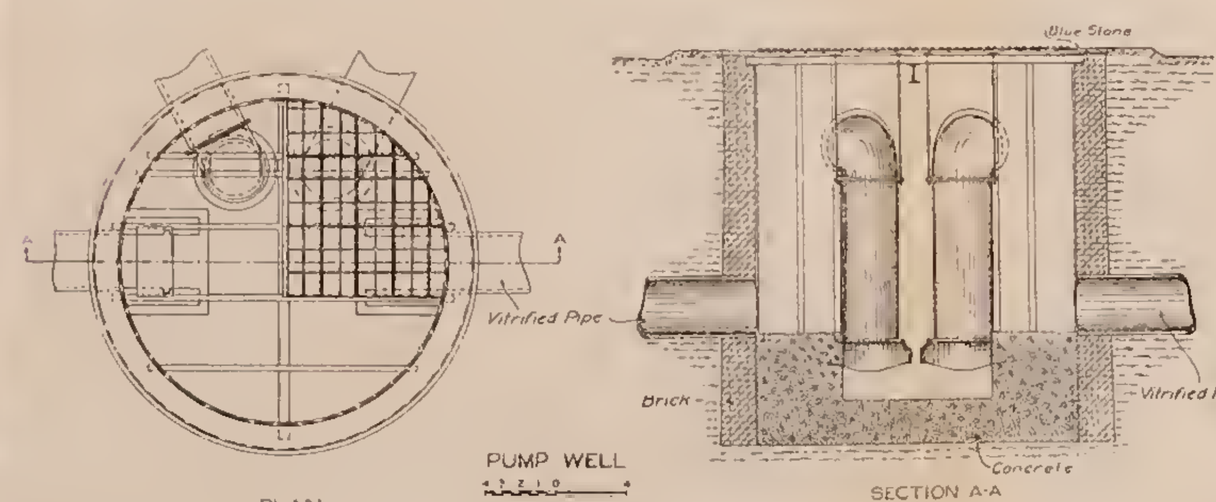
MASSAPEQUA INFILTRATION GALLERY



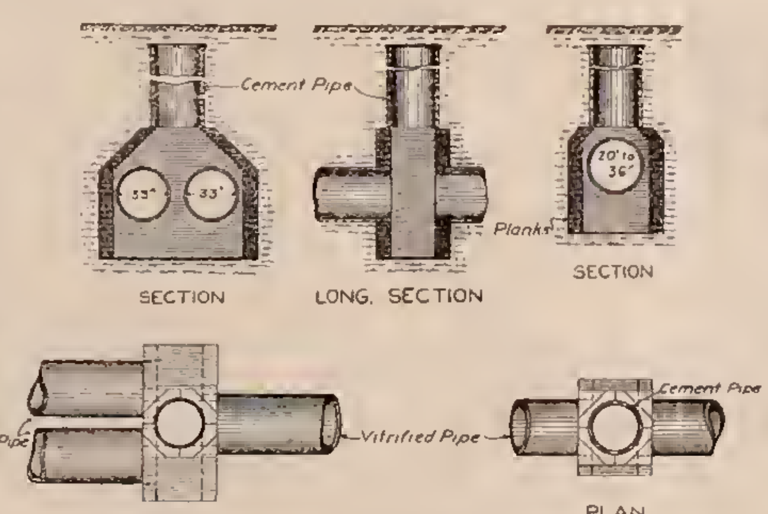
WANTAGH INFILTRATION GALLERY

WANTAGH GALLERY

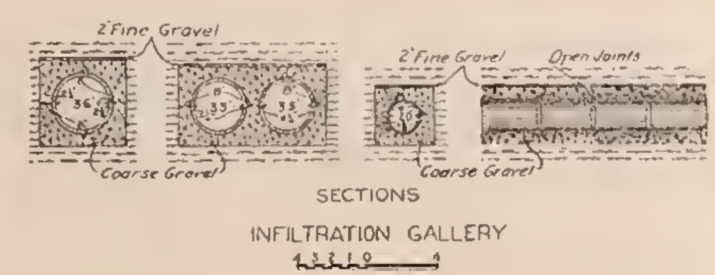
DATE	GALLERY COMPLETED	
Jan 1 1904	From Sta 55·10	To Sta 66·20
Jan 1 1905	" " 55·10	" " 66·20
July 1 1905	" " " 47·30	" " 70·30
Jan 1 1906	" " " 23·10	" " 91·00
July 1 1906	" " " 8·00	" " 104·50
Nov 1906	" " " 0·00	" 122·90



PUMP WELL



SUMPS AND MANHOLES



INFILTRATION GALLERY

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
INFILTRATION GALLERY
From Plans of the Department of Water Supply
FEBRUARY 23 1908

B.W.S. 559

Cost of Water per Million Gallons from Brook

	Quantity of Water Delivered in 1906 Million Gallons	Collection Average Charges			Through Brick Conduit
New watershed: Ground-water	11,804	$17.69	....	....	....
New watershed: General supplies	21,594	....	$14.09	....	$2.93
New watershed: Surface streams	9,790	9.76	....	....	....
		....	....	$21.83	....
Millburn pumping-station	21,594	....	....	....	....
Millburn reservoir	21,594	....	2.36	....	....
Old watershed: Ground-water	14,284	28.92	....	....	....
Old watershed: General supplies	21,124	....	27.33	....	3.94
Old watershed: Surface streams	6,840	24.03	....	....	....
Totals	......	....	....	....	....
Ridgewood pumping-station	42,718	....	....	....	....
Force mains and distribution reservoirs	42,718	....	....	....	....
Distribution system	46,380	....	....	....	....
Water tax collection	46,380	....	....	....	....
Grand totals	......	....	....	....	....

*These charges are for water from the new watershed passing through the 48-inch pipes, built on th

**This charge is for transporting water through the 48-inch pipe-line from Millburn pumping-statio

Test wells of the Brooklyn Department shown thus ⊙
Ground water elevation in test wells in June 1907 shown immediately below serial number; next below this is shown the ground water elevation during December 1906. No record shown --
Ground water contours when ground waters were not being drawn on shown thus — — — —
Ground water contours during period of continuous pumping shown thus - - - - - - - -

Normal water level was taken in June 1907, as test well records were incomplete prior to commencement of pumping in April 1905.

For several months prior to December 1906 the full yield of the gallery had been drawn continuously, and the water levels at this time were typical for periods of maximum draft.

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
WANTAGH INFILTRATION GALLERY
EFFECT OF PUMPING ON GROUND WATER LEVEL
FROM RECORDS OF DEPARTMENT OF WATER SUPPLY

800 0 800 1600 Ft
160 0 160 320 480 M

MAY 8, 1908

Acc L J 196

M. B. BROWN PRINTING & BINDING CO., N. Y.

TABLE 22

Cost of Water per Million Gallons from Brooklyn System, 1901 Through 1906, Based on Interest and Sinking Fund on Outstanding Bonds and Expenditures for Operation and Maintenance

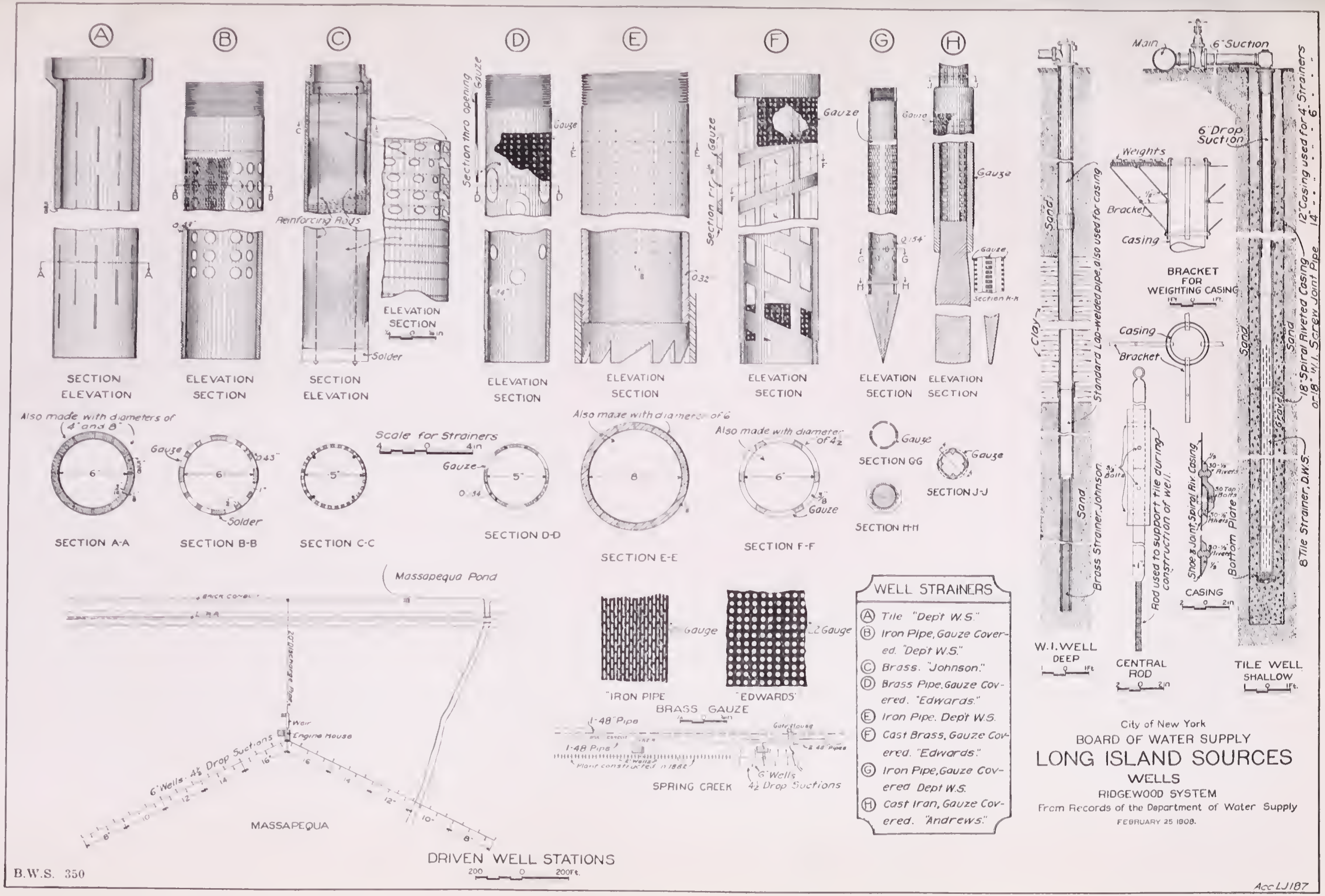
Year	New Construction	Bonds Redeemed	Bonds Outstanding December 31			Totals				Total Amount Supplied in Million Gallons	Average Cost per Million Gallons
			Issued Prior to Consolidation	Issued Subsequent to Consolidation	Total	Interest	Sinking Fund	Operation and Maintenance	Annual Charges		
1901.........	$573,123	....	$14,085,750	$3,010,000	$17,095,750	$646,711	$513,564	$1,063,203	$2,223,478	35,303	$62.98
1902.........	502,031	$1,229,000	12,856,750	3,039,000	15,895,750	609,856	493,493	1,186,276	2,289,625	36,613	62.54
1903.........	624,273	*1,215,000	12,856,750	1,871,500	14,728,250	583,141	468,375	1,429,694	2,481,210	38,234	64.90
1904.........	1,502,896	547,000	12,309,750	4,525,635	16,835,385	623,871	482,058	1,430,739	2,536,668	41,413	61.25
1905.........	1,033,563	500,000	11,809,750	6,781,734	18,591,484	628,176	494,020	1,617,962	2,740,158	43,519	62.97
1906.........	1,359,755	590,000	11,219,750	6,781,734	18,001,484	697,900	473,787	1,779,575	2,951,262	46,380	63.63

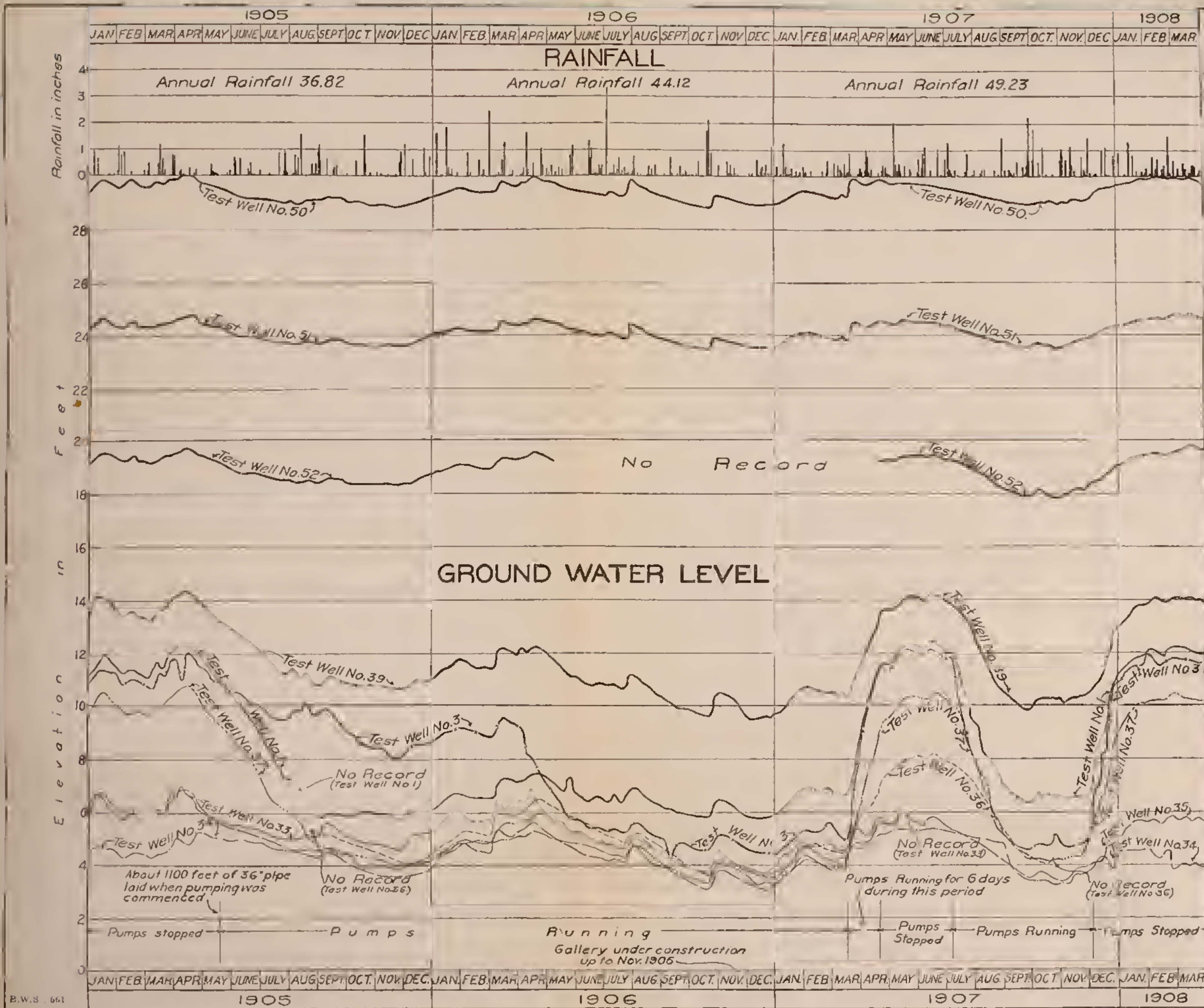
*These bonds were a re-issue made in 1899

added a sinking fund on outstanding bonds, based on the life of the bonds with a three per cent. rate of interest on the accumulation of the sinking fund. The total expenditures have been divided by the total amount supplied by the Brooklyn system, including the Borough stations, giving a resultant average cost per million gallons, as shown in Table 22

For the bonds sold subsequent to the consolidation of Brooklyn with New York City, it was found impossible to determine the exact date of maturity of each issue, as the Comptroller's annual reports show only the date of maturity of bonds issued for water-works purposes and do not separate those used for the Borough of Brooklyn from those for the other boroughs. The error involved, due to the uncertainties in the terms of these bonds, is very small, and would not affect the cost of water per million gallons by more than a few cents.

It will be seen from a comparison of Tables 21 and 22, that the actual cost of the supply is now about $10 per million gallons less than would be the theoretical cost, based on the total cost for works with an assumed life for the various portions of the plant. This is mainly due to the redemption of some bonds, amounting to about $13,191,500, issued to cover the cost of the original works and the subsequent extensions. The redemption of these bonds materially reduces the interest and sinking fund charges, and the actual cost is not comparable with the estimated cost of water from new sources of supply.


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
WELLS
RIDGEWOOD SYSTEM
From Records of the Department of Water Supply
FEBRUARY 25 1908.
WELL STRAINERS
(A) Tile "Dept W.S."
(B) Iron Pipe, Gauze Covered. "Dept W.S."
(C) Brass. "Johnson."
(D) Brass Pipe, Gauze Covered. "Edwards."
(E) Iron Pipe. Dept W.S.
(F) Cast Brass, Gauze Covered. "Edwards."
(G) Iron Pipe, Gauze Covered Dept W.S.
(H) Cast Iron, Gauze Covered. "Andrews."
SECTION ELEVATION
ELEVATION SECTION
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION GG
SECTION H-H
SECTION J-J
Also made with diameters of 4" and 8"
Also made with diameter of 6
Also made with diameter of 4½
Scale for Strainers
Reinforcing Rods
Solder
Gauze
Section thro opening
Section F-F
"IRON PIPE"
"EDWARDS"
BRASS GAUZE
W.I. WELL DEEP
Standard Lap-welded pipe, also used for casing
Brass Strainer, Johnson
Sand
Clay
CENTRAL ROD
Rod used to support tile during construction of well.
BRACKET FOR WEIGHTING CASING
Weights
Bracket
Casing
Shoe & Joint, Spiral Riv. Casing
CASING
TILE WELL SHALLOW
Main
6" Suction
6" Drop Suction
12" Casing used for 4" Strainers
14" " " " 6" "
18" Spiral Riveted Casing or 18" W.I. Screw Joint Pipe
Gravel
8 Tile Strainer, D.W.S.
Bottom Plate
Massapequa Pond
20" Discharge Pipe
Weir
Engine House
6" Wells. 4½ Drop Suctions
MASSAPEQUA
SPRING CREEK
Gate House
6" Wells
4½ Drop Suctions
Plant constructed in 1882
DRIVEN WELL STATIONS
B.W.S. 350
Acc LJ187



The Test Wells in the vicinity of Wantagh Gallery are located on Acc. L.J. 185.

The construction of the Wantagh Gallery was not completed until the end of 1906, as shown on Acc. L.J. 185.

The amount pumped from the gallery is shown on Acc. L.J. 197.

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
GROUND WATER LEVEL
VICINITY OF
WANTAGH INFILTRATION GALLERY
From Records of the Department of Water Supply
FEBRUARY 25 1908

Acc. L.J. 223

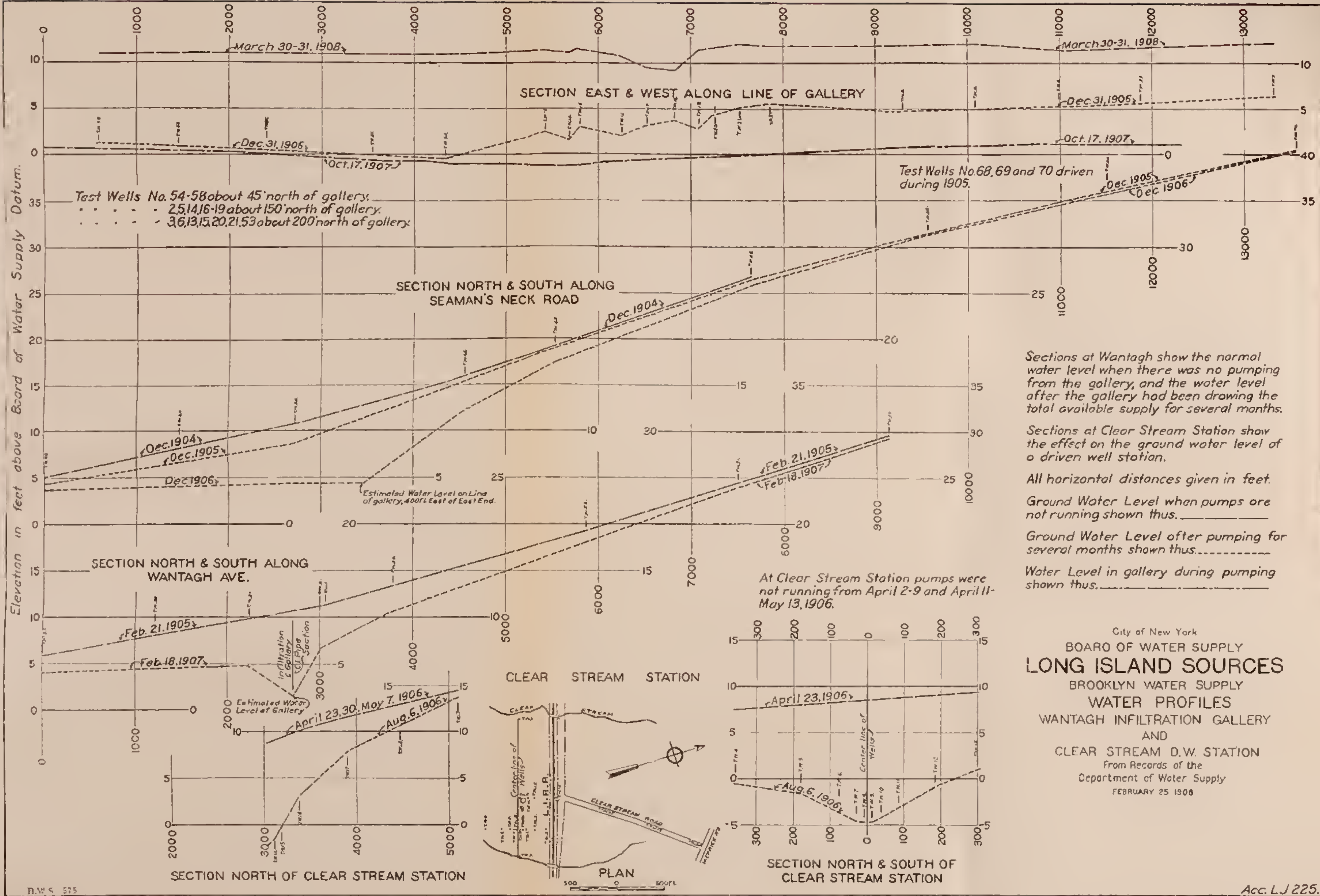
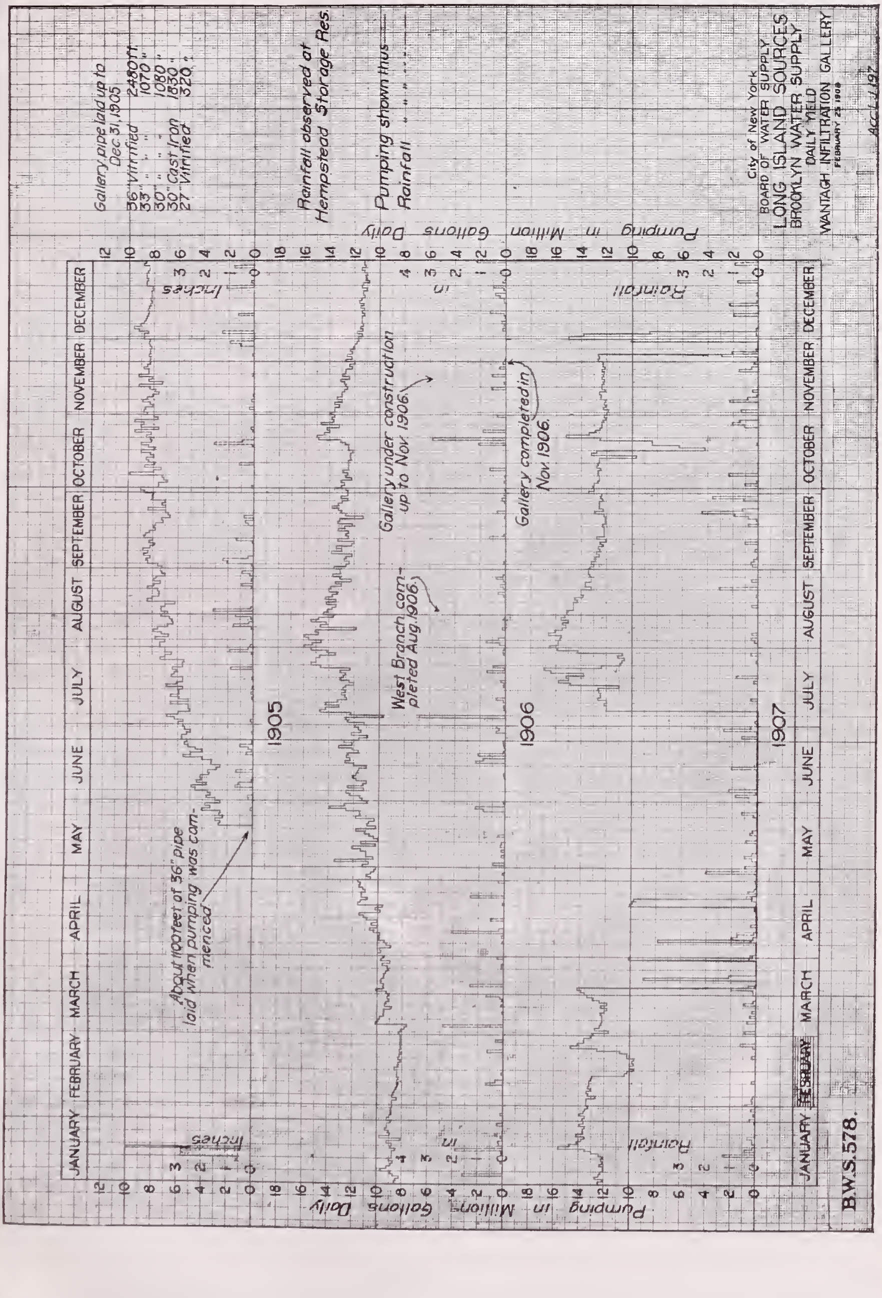

SECTION EAST & WEST ALONG LINE OF GALLERY
March 30-31, 1908
Dec. 31, 1906
Oct. 17, 1907
Test Wells No. 54-58 about 45' north of gallery.
2,5,14,16-19 about 150' north of gallery.
3,6,13,15,20,21,53 about 200' north of gallery.
Test Wells No. 68, 69 and 70 driven during 1905.
SECTION NORTH & SOUTH ALONG SEAMAN'S NECK ROAD
Dec. 1904
Dec. 1905
Dec. 1906
Estimated Water Level on Line of gallery, 400 ft. East of East End.
SECTION NORTH & SOUTH ALONG WANTAGH AVE.
Feb. 21, 1905
Feb. 18, 1907
Infiltration & Gallery
C.I. Pipe Suction
Estimated Water Level of Gallery
Elevation in feet above Board of Water Supply Datum.
At Clear Stream Station pumps were not running from April 2-9 and April 11-May 13, 1906.
April 23, 30, May 7, 1906
Aug. 6, 1906
SECTION NORTH OF CLEAR STREAM STATION
CLEAR STREAM STATION
PLAN
L.I.R.R.
Center line of Wells
CLEAR STREAM ROAD
April 23, 1906
SECTION NORTH & SOUTH OF CLEAR STREAM STATION
Sections at Wantagh show the normal water level when there was no pumping from the gallery, and the water level after the gallery had been drawing the total available supply for several months.
Sections at Clear Stream Station show the effect on the ground water level of a driven well station.
All horizontal distances given in feet.
Ground Water Level when pumps are not running shown thus.
Ground Water Level after pumping for several months shown thus.
Water Level in gallery during pumping shown thus.
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
WATER PROFILES
WANTAGH INFILTRATION GALLERY AND CLEAR STREAM D.W. STATION
From Records of the Department of Water Supply
FEBRUARY 25 1908
B.W.S. 575
Acc. L.J 225.

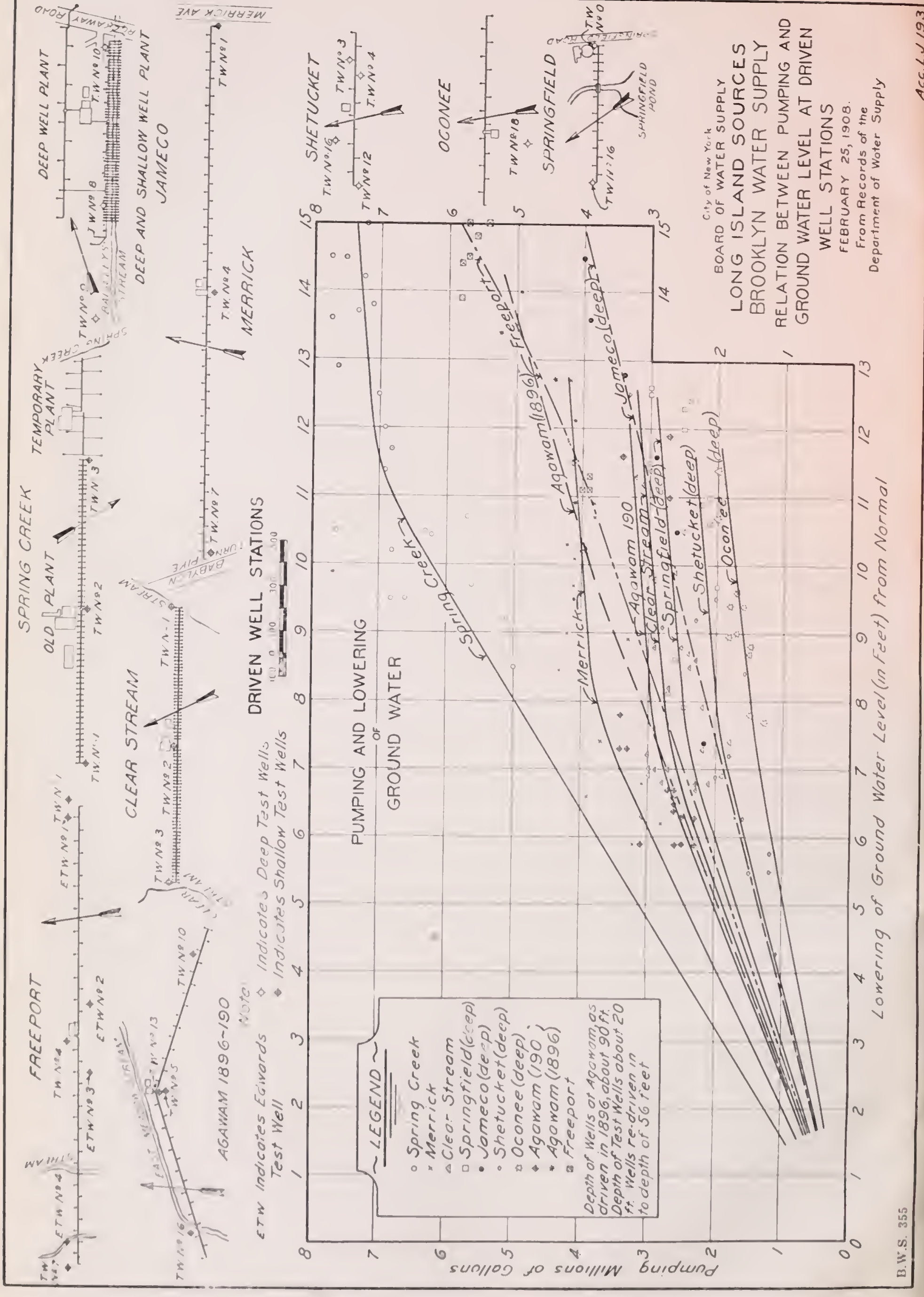
TABLE 24

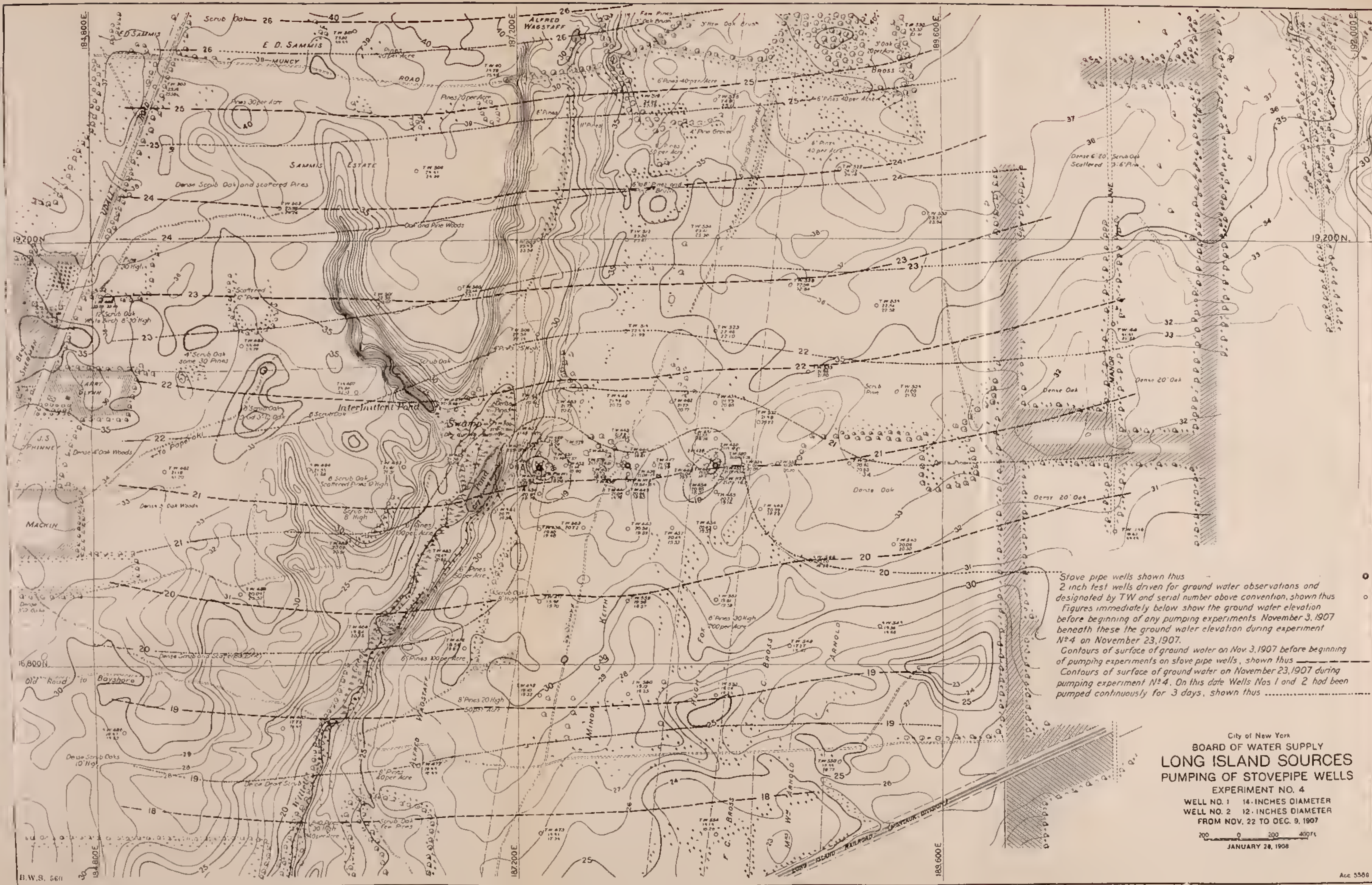
Pumping Experiments on Stovepipe Wells 1, 2 and 3, at Babylon Experiment Station, West Islip, Long Island, from November 1 to December 31, 1907

Experiment	Date 1907 From	Date 1907 To	Total Duration of Experiment Days	Total Duration of Experiment Hours	Well 1, 14 Inches in Diameter: Actual Time of Operation Days	Hours	Average Delivery During This Time Gallons per Day	Lowering of Ground-Water 6 Inches from Well at Close of Experiment Corrected for Change in Water-Table Feet	Loss of Head Corresponding to Average Delivery of Well in Wall of Well Feet	Well 3, 16 Inches in Diameter: Actual Time of Operation Days	Hours	Average Delivery During This Time Gallons per Day	Lowering of Ground-Water 6 Inches from Well at Close of Experiment Corrected for Change in Water-Table Feet	Loss of Head Corresponding to Average Delivery of Well in Wall of Well Feet	Well 2, 12 Inches in Diameter: Actual Time of Operation Days	Hours	Average Delivery During This Time Gallons per Day	Lowering of Ground-Water 6 Inches from Well at Close of Experiment Corrected for Change in Water-Table Feet	Loss of Head Corresponding to Average Delivery of Well in Wall of Well Feet	Total Pumpage of Station During Experiment Gallons	Total Average Pumping of Station During Entire Experiment Gallons per Day
1.........	Nov. 4	Nov. 13	9	1¼	0	21¼	865,170	1.99	5.1	8	8¾	975,200	10.5*	7.1*	7	12½	372,480	3.99	5.45	11,745,400	1,297,000
2.........	Nov. 13	Nov. 20	7	0	..	..	....	....	....	7	0	1,113,690	12.0*	8.5*	..	..	....	....	....	7,795,850	1,113,700
3.........	Nov. 20	Nov. 22	1	23½	1	18	468,430	7.21	6.1	1	20¾	1,036,290	11.7*	8.4*	1	4	523,460	5.06	8.9	3,362,700	1,700,000
4.........	Nov. 22	Dec. 9	17	4	16	17½	989,660	7.51	8.5	..	..	....	....	...	16	20	726,160	6.10	10.5	28,791,950	1,676,900
5.........	Dec. 16	Dec. 18	2	3½	..	..	....	....	....	2	3½	1,014,150	10.78	5.72	..	..	....	....	....	2,171,950	1,012,100
6.........	Dec. 18	Dec. 28	10	11	10	9½	827,690	6.56	7.1	9	18½	877,030	12.24	5.93	10	4¼	710,460	6.07	9.4	24,300,230	2,323,000

*At this time the 2-inch test-well 6 inches from casing was choked. Observations were made in 2-inch test-well 20 feet away. These values shown are worked up from curve of relative lowering of ground-water existing between these two wells under similar conditions at other times


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
DAILY YIELD
WANTAGH INFILTRATION GALLERY
FEBRUARY 25 1908
Gallery pipe laid up to Dec. 31, 1905
36" Vitrified 2480 ft.
33" " 1070 "
30" " 1080 "
30" Cast Iron 1830 "
27" Vitrified 320 "
Rainfall observed at Hempstead Storage Res.
Pumping shown thus
Rainfall " "
Pumping in Million Gallons Daily
Inches
Rainfall
1905
1906
1907
About 1100 feet of 36" pipe laid when pumping was commenced
West Branch completed Aug. 1906.
Gallery under construction up to Nov. 1906.
Gallery completed in Nov. 1906.
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
B.W.S. 578.


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
BROOKLYN WATER SUPPLY
RELATION BETWEEN PUMPING AND
GROUND WATER LEVEL AT DRIVEN
WELL STATIONS
FEBRUARY 25, 1908.
From Records of the
Department of Water Supply
Acc. L.J 193
PUMPING AND LOWERING
OF
GROUND WATER
DRIVEN WELL STATIONS
~ LEGEND ~
Spring Creek
Merrick
Clear Stream
Springfield (deep)
Jameco (deep)
Shetucket (deep)
Oconee (deep)
Agawam (190)
Agawam (1896)
Freeport
Depth of Wells at Agawam as driven in 1896, about 90 ft. Depth of Test Wells about 20 ft. Wells re-driven in to depth of 56 feet
Note: ETW Indicates Edwards Test Well
◇ Indicates Deep Test Wells
◆ Indicates Shallow Test Wells
Pumping Millions of Gallons
Lowering of Ground Water Level (in Feet) from Normal
FREEPORT
SPRING CREEK
OLD PLANT
TEMPORARY PLANT
DEEP WELL PLANT
DEEP AND SHALLOW WELL PLANT
JAMECO
ROCKAWAY ROAD
MERRICK AVE
MERRICK
CLEAR STREAM
BABYLON TURNPIKE
AGAWAM 1896-190
SHETUCKET
OCONEE
SPRINGFIELD
SPRINGFIELD ROAD
SPRINGFIELD POND
B.W.S. 355



Stove pipe wells shown thus
2 inch test wells driven for ground water observations and designated by TW and serial number above convention, shown thus
Figures immediately below show the ground water elevation before beginning of any pumping experiments November 3, 1907 beneath these the ground water elevation during experiment Nº4 on November 23, 1907.
Contours of surface of ground water on Nov. 3, 1907 before beginning of pumping experiments on stove pipe wells, shown thus
Contours of surface of ground water on November 23, 1907 during pumping experiment Nº4. On this date Wells Nos 1 and 2 had been pumped continuously for 3 days, shown thus
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVEPIPE WELLS
EXPERIMENT NO. 4
WELL NO. 1 14-INCHES DIAMETER
WELL NO. 2 12-INCHES DIAMETER
FROM NOV. 22 TO DEC. 9, 1907
200 0 200 400 Ft
JANUARY 28, 1908
Acc 5588
B.W.S. 560
E. D. SAMMIS
MUNCY
ROAD
ALFRED WAGSTAFF
SAMMIS ESTATE
Dense Scrub Oak and scattered Pines
Oak and Pine Woods
Intermittent Pond
Swamp
19,200 N.
16,800 N.
Old Road to Bayshore
MACKIN
J. S. PHINNEY
Dense Oak
Dense 20' Oak
MANOR LANE
MINOR
KEITH
BROSS
ARNOLD
LONG ISLAND RAILROAD
183,800 E.
187,200 E.
189,600 E.
192,000 E.

APPENDIX 5

DESIGN OF WELL SYSTEM

BY WALTER E. SPEAR, DIVISION ENGINEER

The California stovepipe well gave early promise of being the type best adapted for the proposed development of the Suffolk County ground-waters by means of a continuous line of wells. Accordingly, plans were made at the inception of the Long Island investigations to drive wells of this kind, and to pump them experimentally in order to determine the proper size, depth and spacing for local conditions. It was not anticipated that these experiments could be made on a scale sufficiently large to definitely learn from them the yield of the Suffolk County watershed; the operation of the Ridgewood works in western Long Island provided enough data to estimate this. It was expected, however, that these experiments would give the necessary information by which to design the wells for the final development, should the stovepipe well prove satisfactory.

EXPERIMENTS ON STOVEPIPE WELLS

Description of Wells and Driving Rig

Early in 1907 permission was secured to occupy private lands in West Islip, not far from the department office at Babylon, and on assembling the stovepipe well rig that was built for the stovepipe well experiments, three wells, 12, 14 and 16 inches in diameter respectively, were driven, 500 feet apart, on an east and west line as nearly as possible where the final line of the proposed collecting works would be located. The first, Well 1, 14 inches in diameter, was pushed to a depth of 812 feet; but as no water bearing strata were found below 100 feet, the other wells, 2 and 3, 12 and 16 inches in diameter, respectively, were made only about 200 feet in depth.

These wells are double casings of the common riveted type, and most of the material first used came from Los Angeles, where portions of the driving rig were also purchased. These casings are made in sections or "joints" as they are called, 24 inches in length, of hard red steel, each joint having 16 soft iron rivets in the longitudinal seam. The outer and inner joints fit together tightly, and the ends of the joints of either

line butt in the center of the joints of the other without any round-about rivets above the first 17 feet of the well. The first section of this length, the starter, which is made rigid by many additional rivets in order that the well may go down vertically, is equipped at the bottom with a forged steel cutting shoe.

One inner and one outer joint are added at one time to the well as it is pushed down by hydraulic jacks, which are anchored to a plank and timber platform buried about 10 feet below the surface about the well. The material penetrated by the casing is removed by means of a heavy sand bucket operated by the peculiar walking-beam rig originally designed in California to drive the stovepipe casing. The rig built by the Board for this work is shown on Plate 14, in which may also be seen the sand bucket, the drive head, and the casing at Well 2, West Islip.

After being driven, the casings of these three wells at the experiment station were perforated for a portion of their length to admit the ground-water from the coarser strata of the yellow gravels. The character of the yellow gravels encountered in these wells and the depth of the strata perforated, are shown in Table 23.

After each well was perforated, the coarser material that came through the cuts was taken out with the sand bucket, and then an air-lift system was installed, and the well pumped for several days until all the fine sand had been removed from the strata near the perforated portion of the casing. The gravel left about the cuts by the removal of the sand formed a filter that afterwards served to collect the ground-water and exclude the sand. Screened gravel was placed about each casing during this preliminary pumping to cover and make a filter about the upper cuts in the casing that were exposed to fine material by the settling away of the coarse gravel that originally lay about these upper perforations.

Equipment for Pumping Experiments

The air for the pumping system was delivered to these wells through a 3-inch line by an Ingersoll-Sargeant 10-inch by 12¼-inch by 14-inch compressor, purchased by the Board, and another, a Rand 18-inch by 18-inch by 30-inch machine, hired on a monthly rental for the pumping experiments. Together these machines had a capacity of about 700 cubic feet of free air per minute. Steam for these compressors was fur-

Stovepipe well rig at Well 2. West Islip.

TABLE 23

CHARACTER OF STRATA AND DEPTH OF PERFORATIONS IN WELLS AT BABYLON EXPERIMENT STATION

West — East

Notes: Surface of Ground (0 ft). Ground Water (about 10 ft). Sea Level (about 33 ft). Scale: Depth below Surface of Ground in feet (0, 5, 10, … 100).

Well No. 1 — Diameter 14 inches

Sample No.	Effective Size m.m.	Uniformity Coefficient	Perforations
1	0.35	2.3	
2	0.47	4.7	
3	0.73	39.7	
4	0.51	21.6	Perforated 36 feet (from about 14 ft)
5	0.66	23.2	
7	0.29	1.7	
8	0.33	1.8	(to about 50 ft)
9	0.28	2.0	
10	0.36	1.4	
11	0.35	1.5	
12	0.31	1.5	
13	0.36	2.2	
14	0.39	23.1	Perforated 11 feet (from about 90 ft)
15	1.30	5.2	
16	2.20	13.6	(to about 101 ft)
Total Depth above Black Clay	102 feet		
Average Effective Size	0.44 m.m.		

Well No. 3 — Diameter 16 inches

Sample No.	Effective Size m.m.	Uniformity Coefficient	Perforations
1	0.37	3.0	
2	0.31	4.8	
3	0.55	4.2	
4	0.68	2.5	
5	2.00	11.5	
6,7	1.30	13.9	Perforated 31 feet (from about 14 ft)
8,9	0.98	17.9	
10	2.00	6.5	
11	0.50	38.0	
12	0.62	32.2	
13	0.51	25.5	
14	0.60	30.8	
15	0.42	2.4	
16	0.47	5.9	
17	0.52	32.6	
18	0.37	35.1	
19	0.36	2.1	
20	0.42	8.1	
21	0.37	2.5	
22	0.35	2.6	
23	0.35	2.0	(to about 45 ft)
24	0.34	2.2	
25	0.33	1.9	
26	0.29	1.9	
27	0.35	1.9	
28	0.26	1.8	
29	0.29	1.8	
30	0.32	1.5	
31	0.23	1.8	
32	0.26	1.6	
33	0.27	1.8	
34	0.28	1.5	
35	0.26	1.5	
36	0.34	1.3	
37	0.24	1.7	
38	0.23	1.8	
39	0.22	1.7	
40	0.26	1.6	
41	0.27	1.5	
42	0.27	1.5	
43	0.35	19.1	Perforated 8.3 feet (from about 88 ft)
44	0.37	25.4	
45	0.57	25.4	
46	0.65	40.0	
47	0.37	2.4	(to about 96 ft)
48	0.31	1.5	
49	0.27	1.5	
50	0.32	1.5	
Total Depth above Black Clay	113 feet		
Average Effective Size	0.49 m.m.		

Well No. 2 — Diameter 12 inches

Sample No.	Effective Size m.m.	Uniformity Coefficient	Perforations
1	0.43	3.7	
2	*0.51		
3	0.59	6.6	
	0.60	4.7	
5A	0.45	2.4	
5B	10.5	2.7	
6	1.35	12.2	
7	0.33	1.8	Perforated 30 feet (from about 14 ft)
8	1.80	5.3	
9	0.90	3.7	
10	0.63	12.3	
11	0.54	4.8	
12	0.32	1.6	
13	0.37	2.4	
14	0.37	4.0	
15	0.34	1.8	
16	0.40	1.9	
17	0.32	1.6	
18	0.28	1.8	
19	0.30	1.7	
20	0.29	1.7	(to about 44 ft)
21	0.29	1.7	
22	0.32	2.2	
23	0.30	2.5	
24	0.28	1.7	
	0.36	2.2	
26	0.25	1.7	
27	0.30	1.6	
28	0.22	1.6	
29	0.26	1.6	
30	0.23	1.8	
31	0.23	1.8	
32	0.26	1.6	
33	0.20	2.0	
34	0.19	2.0	
35	0.15	2.1	
36	0.22	1.8	
37	0.19	1.9	
38	0.18	2.0	
39A&B	0.60	18.3	Perforated 3 feet (about 88–91 ft)
40			
41	2.9	7.6	
Total Depth above Black Clay	91 feet		
Average Effective Size	0.63 m.m.		

*60% finer than

B.W.S. 117

nished by two 80-H. P. horizontal Nagle boilers, the property of the Board, which were housed with the compressors in a temporary station near Well 1. An idea of this power-station, the weirs, flumes and the air equipment at the wells may be gained from Plates 15 to 18, inclusive.

On the completion of the wells, and the installation of the pumping system, a sharp-crested weir with an autographic recording gage was set up at each to measure the pumpage, and connections were made to a long, wooden flume that discharged all the water pumped into a brook 3,000 feet south of the station, beyond the inflection of the water-table toward the wells. The casing of the air-lift system was adjusted in the wells to secure a reasonable efficiency for the air lift, and after some preliminary tests, experiments were begun on November 1, and carried on until December 28, 1907.

The plant was run continuously during this time on three shifts of eight hours each, except for short interruptions for changes and repairs, and a week lost in December because of a shortage in coal. No illusion was entertained regarding the efficiency of the air-lift system; one of the most serious problems during the experiments was to keep the plant supplied with coal, of which six or seven tons were burned daily, when running at full capacity. The air-lift system was adopted for these pumping tests because it was the cheapest to install and it was necessary, at first, in cleaning up the filters of the wells.

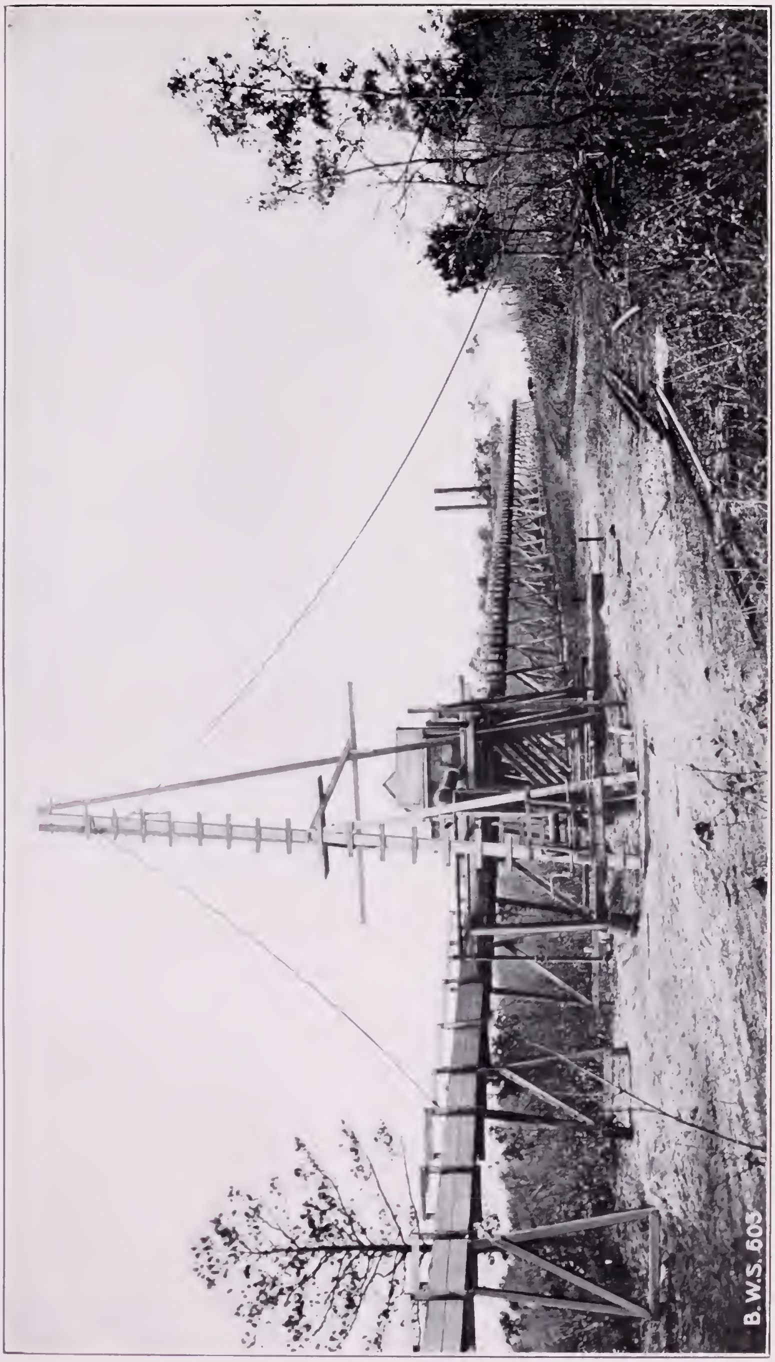
Description of Pumping Experiments

The three wells were pumped singly, in groups of two, and then altogether to determine the interference of one well with another. In order to ascertain the effect of the pumping on the ground-water surface, 101 2-inch test-wells were driven about the stovepipe wells within a radius of 2,000 to 3,000 feet and levelled upon for daily observations of the hight of the ground-water surface.

Six series of experiments were made during the two months in which the experiment station was in operation. The results of the experiments are summarized in Table 24 following, and the main facts are shown graphically on Sheet 64, Acc. L. 607.

The last three series of experiments, 4, 5 and 6, have been worked up in greater detail, and are exhibited on Sheets 65 to 69, Accs. L. 334 to L 338, inclusive, and on Sheets 61, 62 and 63, Accs. 5589, 5590 and 5588.

General view of boiler and compressor house, showing Well 1 and flume from Wells 2 and 3.



Well 3, looking westerly along flume toward boiler-house.

Well 3, looking easterly, showing measuring weir and instrument house.

Well 2, looking westerly along flume, showing casing, air-lift equipment and measuring box.


Stove pipe wells shown thus
2 inch test wells driven for ground water observations and designated by TW and serial number above convention, shown thus
Figures immediately below show the ground water elevation at beginning of this pumping experiment on December 16, 1907; figures beneath these the ground water elevation at end of this experiment December 18, 1907.
Where only one ground water elevation shows it represents the ground water elevation on December 18, 1907.
Contours of surface of ground water just before beginning of experiment No. 5 on December 16, 1907 after an interval of seven days during which there was no pumping; shown thus
Contours of surface of ground water on December 18, 1907 after two days of continuous pumping from Well No. 3 at end of experiment No. 5, shown thus
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVEPIPE WELLS
EXPERIMENT NO. 5
WELL NO. 3 16 · INCHES DIAMETER
FROM DEC. 16 TO DEC. 18, 1907
JANUARY 28, 1908
E. D. SAMMIS
SAMMIS ESTATE
ALFRED WAGSTAFF
LARRY GLYNN
J. S. PHINNEY
MACHIN
Intermittent Pond
Swamp
To Paperoki
Old Road to Bayshore
MANOR LANE
19,200 N.
16,600 N.
184,800 E.
187,200 E.
189,600 E.
192,000 E.
B.W.S. 558
Acc 5880

PUMPING EXPERIMENTS ON STOVEPIPE WELLS 1,
NOVEMBE

Experiment	Date 1907 From	Date 1907 To	Total Duration of Experiment Days	Total Duration of Experiment Hours	Actual Time of Operation Days	Actual Time of Operation Hours	Well 1, 14 Inches in Diameter: Average Delivery During This Time Gallons per Day	Well 1, 14 Inches in Diameter: Lowering of Ground-Water 6 inches from Well at Close of Experiment Corrected for Change in Water-Table Feet	Well 1, 14 Inches in Diameter: Loss of Head Corresponding to Average Delivery of Well in Wall of Well Feet
1.........	Nov. 4	Nov. 13	9	1¼	0	21¼	865,170	1.99	5.1
2.........	Nov. 13	Nov. 20	7	0	..	..	....	....	....
3.........	Nov. 20	Nov. 22	1	23½	1	18	468,430	7.21	6.1
4.........	Nov. 22	Dec. 9	17	4	16	17½	989,660	7.51	8.5
5.........	Dec. 16	Dec. 18	2	3½	..	..	....	....	....
6.........	Dec. 18	Dec. 28	10	11	10	9½	827,690	6.56	7.1

*At this time the 2-inch test-well 6 inches from casing was choked. Observations were made in 2-
these two wells under similar conditions at other times

TABLE 24

.. AND 3, AT BABYLON EXPERIMENT STATION, WEST ISLIP, LONG ISLAND, FROM
...1 TO DECEMBER 31, 1907

Well 3, 16 Inches in Diameter					Well 2, 12 Inches in Diameter						
...ual Ti... of ...ation: ...ays	...ours	Average Delivery During This Time Gallons Per Day	Lowering of Ground-Water 6 Inches From Well at Close of Experiment Corrected for Change in Water-Table Feet	Loss of Head Corresponding to Average Delivery of Well in Wall of Well Feet	Actual Time of Operation: Days	Hours	Average Delivery During This Time Gallons Per Day	Lowering of Ground-Water 6 Inches From Well at Close of Experiment Corrected for Change in Water-Table Feet	Loss of Head Corresponding to Average Delivery of Well in Wall of Well Feet	Total Pumpage of Station During Experiment Gallons	Total Average Pumping of Station During Entire Experiment Gallons Per Day
8	8¾	975,200	10.5*	7.1*	7	12½	372,480	3.99	5.45	11,745,400	1,297,000
7	0	1,113,690	12.0*	8.5*	..	..	....	....	....	7,795,850	1,113,700
1	20¾	1,036,290	11.7*	8.4*	1	4	523,460	5.06	8.9	3,362,700	1,700,000
.	..	....	....	....	16	20	726,160	6.10	10.5	28,791,950	1,676,900
2	3½	1,014,150	10.78	5.72	..	..	....	....	....	2,171,950	1,012,100
9	18½	877,030	12.24	5.93	10	4¼	710,460	6.07	9.4	24,300,230	2,323,000

...in test-well 20 feet away. These values shown are worked up from curve of relative lowering of ground-water existing between

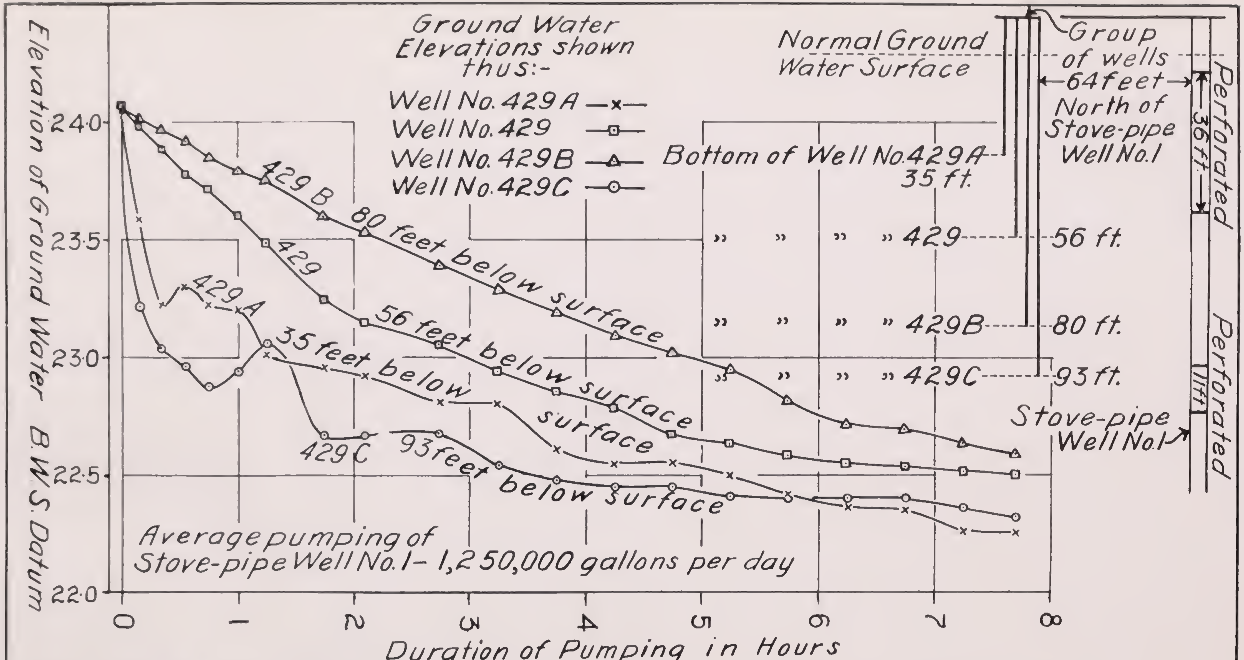
RELATIVE PRESSURE IN GROUND-WATER AT VARIOUS DEPTHS

The 2-inch test-wells driven to map the surface of the ground-water during these experiments just described, were from 40 to 50 feet in depth; a few near the stovepipe wells were somewhat deeper. These wells had open ends without screen sections and the hight of water in them represented the ground-water head or pressure in the sands at the bottom of the well.

The results of the first six series of experiments suggested that perhaps the pressure gradients in all the yellow sands and gravels were not coincident, during the experiments, with the slopes of the surface of saturation or surface pressure gradients that had been so carefully mapped by means of these test-wells. Accordingly, a group of four test-wells was put in at a point 64 feet north of Stovepipe Well 1, at depths of 35, 56, 80 and 93 feet respectively, and the hight of water in them observed during the pumping of this stovepipe well on May 14, 1908.

The results of these ground-water observations, of Experiment 7, are shown graphically on Sheet 58, Acc. L 679 and Sheet 59, Acc. L 680. The test-wells 35 and 93 feet in depth were in the coarser material in which Well 1 was perforated and they responded quickly when pumping began. The test-wells 56 and 80 feet deep were in the finer strata between the upper and lower perforated sections of the large well, and the lowering of the water in them, which represented the ground-water pressure at these depths, lagged six inches or more behind the other wells during the first few hours. At the end of the day's pumping, the test-wells indicated that the ground-water was about three inches lower in those strata opposite the perforations than in the finer sands and gravel between them. There was evidently about three inches greater loss of head in the water flowing from the intermediate strata to the well than in the strata that were perforated. The pressure in the deep gravels was nearly coincident with the surface of the ground-water as shown by the shallow well.

The hight of ground-water in all the wells was practically the same before pumping, and the results of the subsequent observations indicated that the slopes of the ground-water approaching the wells that were determined during the previous six experiments represented the pressure gradients in all the yellow water bearing strata without sensible error.



Note that the hydrostatic heads and pressures of ground water in finer strata between perforations were about 0·25 feet less than in the coarser material opposite the top and bottom screen sections, and that the pressures between the screen sections lagged behind those nearer the perforated sections.

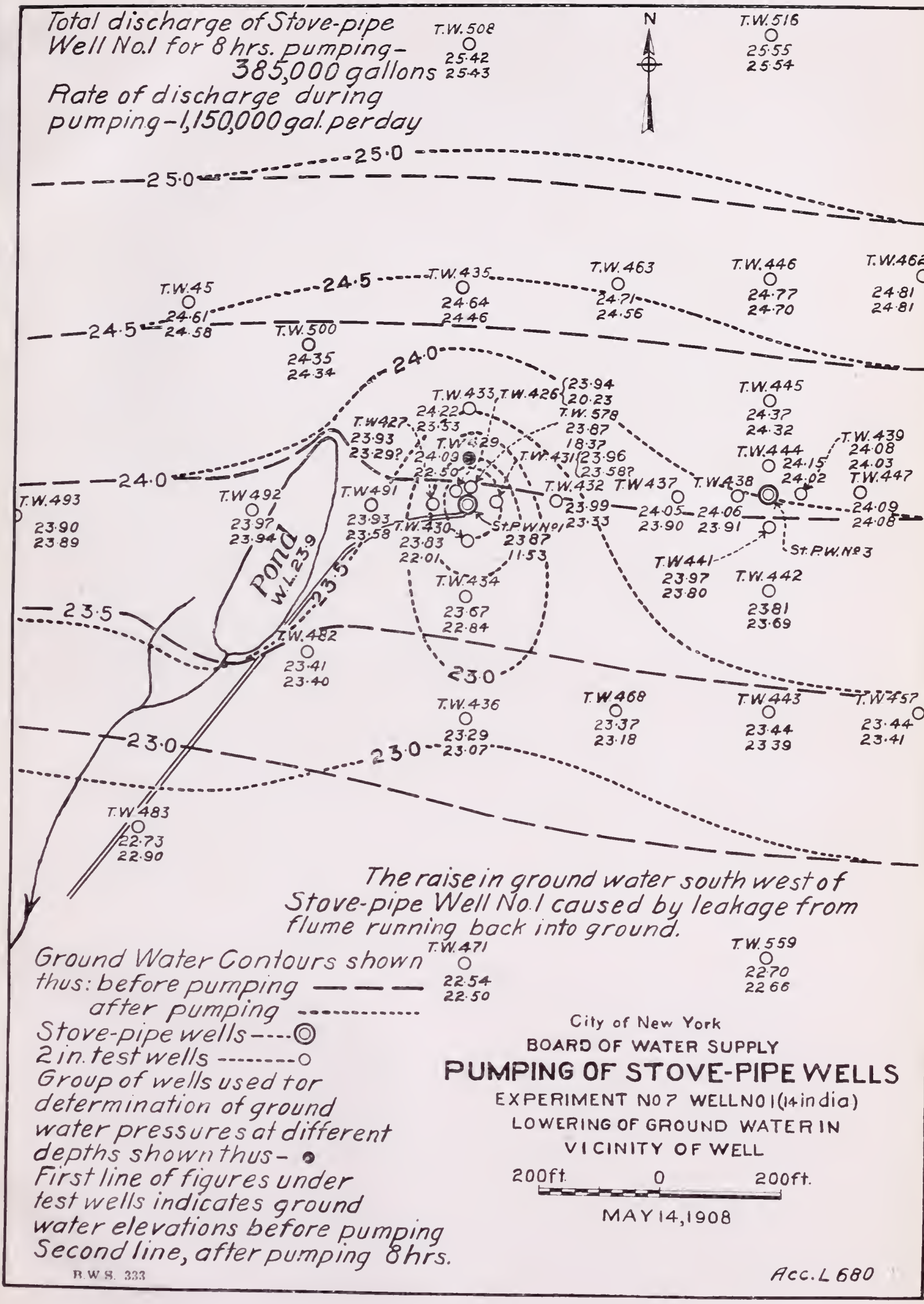
City of New York
BOARD OF WATER SUPPLY

PUMPING OF STOVE-PIPE WELL

EXPERIMENT NO. 7 WELL NO. 1 (14 in. dia.)
RELATIVE GROUND WATER PRESSURES
AT VARIOUS DEPTHS 64 FEET NORTH
OF WELL
May 14, 1908

B.W.S. 511

Acc L 679


Total discharge of Stove-pipe Well No.1 for 8 hrs. pumping – 385,000 gallons
Rate of discharge during pumping – 1,150,000 gal. per day
N
T.W. 508 25·42 25·43
T.W. 516 25·55 25·54
25·0
24·5
T.W. 45 24·61 24·58
T.W. 435 24·64 24·46
T.W. 463 24·71 24·56
T.W. 446 24·77 24·70
T.W. 462 24·81 24·81
T.W. 500 24·35 24·34
24·0
T.W. 433
T.W. 426 23·94 20·23
T.W. 578 23·87 18·37
T.W. 445 24·37 24·32
T.W. 427 23·93 23·29?
24·22 23·53
T.W. 429 24·09 22·50
T.W. 431 23·96 23·58?
T.W. 444 24·15 24·02
T.W. 439 24·08 24·03
T.W. 447 24·09 24·08
T.W. 493 23·90 23·89
T.W. 492 23·97 23·94
T.W. 491 23·93 23·58
T.W. 430 23·83 22·01
St. P. W. No. 1 23·87 11·53
T.W. 432 23·99 23·33
T.W. 437 24·05 23·90
T.W. 438 24·06 23·91
St. P. W. No. 3
Pond W.L. 23·9
T.W. 441 23·97 23·80
T.W. 442 23·81 23·69
T.W. 434 23·67 22·84
23·5
T.W. 482 23·41 23·40
23·0
T.W. 436 23·29 23·07
T.W. 468 23·37 23·18
T.W. 443 23·44 23·39
T.W. 457 23·44 23·41
T.W. 483 22·73 22·90
The raise in ground water south west of Stove-pipe Well No.1 caused by leakage from flume running back into ground.
T.W. 471 22·54 22·50
T.W. 559 22·70 22·66
Ground Water Contours shown thus: before pumping
after pumping
Stove-pipe wells
2 in. test wells
Group of wells used for determination of ground water pressures at different depths shown thus –
First line of figures under test wells indicates ground water elevations before pumping
Second line, after pumping 8 hrs.
City of New York
BOARD OF WATER SUPPLY
PUMPING OF STOVE-PIPE WELLS
EXPERIMENT NO 7 WELL NO 1 (14 in dia)
LOWERING OF GROUND WATER IN VICINITY OF WELL
200ft. 0 200ft.
MAY 14, 1908
B.W.S. 333
Acc. L 680

DISCUSSION OF RESULTS

Spacing of Wells

It appears from the experiments, Series 1 to 6, that Wells 1 and 2, which are 1,000 feet apart, did not interfere materially with each other. When all three wells were in operation, however, the discharge of the middle well, 3, was evidently reduced from 20 to 25 per cent. below the yield that was obtained when being pumped alone to the same depth. That is, with the strata existing at this station, there would be this amount of interference between the units of a continuous line of wells spaced 500 feet apart.

Some interference, perhaps 10 or 15 per cent., is necessary between wells spaced as in these experiments, along a line at right angles to the ground-water movement in order that the entire flow may be intercepted. The wells should not, however, be placed any nearer together than is necessary to effect this result, by a moderate lowering of the water-table. The inflection of the ground-water surface midway between two wells is the surest index of existence of any loss of water between them. Referring to Sheet 66, Acc. L 335, Experiment 4 on Wells 1 and 2, which are 1,000 feet apart, the transverse section through Well 3, which was not being pumped, and which is half-way between Wells 1 and 2, shows that the water surface below or south of this well, 3, sloped slightly toward the cones of depression. The slope was, however, small, and it is barely possible that the pressure lines in some stratum finer than that penetrated by the test-wells was not equally depressed and perhaps some flow to the south took place. A greater lowering of the water in Wells 1 and 2, would surely have prevented any loss between these wells, but it would appear to be better practice, under the local geological conditions, to place the wells somewhat nearer together than 1,000 feet.

The results of the last experiment, 6, which are exhibited on Sheets 68 and 69, Accs. L 337 and L 338, and Sheet 63, Acc. 5588, indicate that a spacing of 500 feet is unnecessarily small in the material in which these wells are driven. Evidently a spacing intermediate between 500 and 1,000 feet, perhaps 700 feet, would answer at this location. The proper distance between such wells would vary along the line of the collecting works with the depth and coarseness of the water

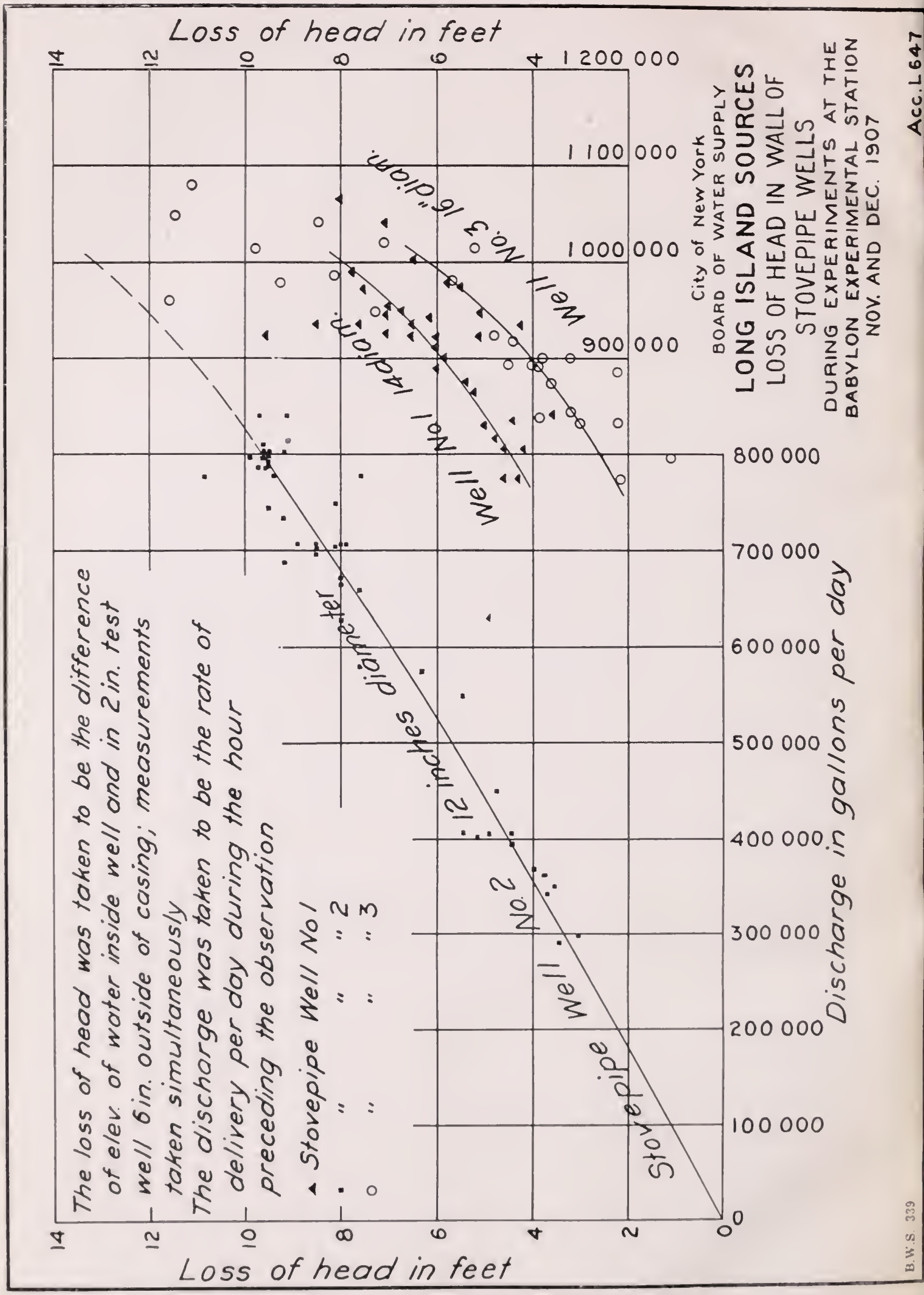
bearing strata, and the area and probable yield of the tributary watershed. In but few localities would it probably be safe to space these large wells over 1,000 feet, and it seems unlikely that it would be necessary, even where the material is fine, or in the valleys where the ground-waters from the upland are concentrated, to place these wells much nearer together than 500 feet.

Size of Wells and Length of Screen Section

One important conclusion to be drawn from these experiments on the stovepipe wells is that the losses of head through the wall of the wells and the gravel filters outside, were too great and should be reduced in the wells of the final development. This loss of head varied in these experiments with the diameter of the casing, and the yield of the well, as shown on Sheet 60, Acc. L 647. It was also affected by the length of perforated section; for example, the losses of head in Well 1, were comparatively small because the length of perforation, or the screen section is greater in this well than in the other two. The losses in Well 2 were large because of the small depth of perforated section, and because the material surrounding it is somewhat finer than about the other two wells. The losses corresponding to a uniform draft of 1,000,000 gallons per day may be estimated from this diagram for each size of well as follows:

Well	Size of Well Inside Diameter	Loss of Head in Well of Casing
2	12 inches	13 feet
1	14 "	8 "
3	16 "	6.2 "

It appears that the losses of entrance to the 12-inch well occurred for the most part, in the filter about the casing, because the losses were directly proportional to the velocity or to the discharge; whereas, a larger proportion of the losses for the larger yields in Wells 1 and 3, which were surrounded by coarse gravel, evidently took place in the perforations of the casing where the flow would correspond more nearly to the discharge through orifices, and the loss would vary with the square of the velocity. The results show that there should have been more perforations in the casings of Wells 1 and 3.


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
LOSS OF HEAD IN WALL OF
STOVEPIPE WELLS
DURING EXPERIMENTS AT THE
BABYLON EXPERIMENTAL STATION
NOV. AND DEC. 1907
Loss of head in feet
Discharge in gallons per day
0
100 000
200 000
300 000
400 000
500 000
600 000
700 000
800 000
900 000
1 000 000
1 100 000
1 200 000
0
2
4
6
8
10
12
14
Well No. 3 16" diam.
Well No 1 14 diam.
Stovepipe Well No. 2 12 inches diameter
The loss of head was taken to be the difference of elev. of water inside well and in 2 in. test well 6 in. outside of casing; measurements taken simultaneously
The discharge was taken to be the rate of delivery per day during the hour preceding the observation
Stovepipe Well No 1
" " " 2
" " " 3
Acc. L647

The loss of head in even the 16-inch well, corresponding to a discharge of 1,000,000 gallons per day, was 6.2 feet, or about 20 per cent. of the total lift during the experiment, and this would not be far from 25 per cent. of the lift into the proposed full aqueduct at this point. The additional lift occasioned by their loss would represent a constant and unnecessary expense in the operation of the proposed works, and means should be taken to avoid it. The loss of head in the wall of a well is often overlooked in operating ground-water works. The normal losses of head in the casings of the wells on the Ridgewood system is from 6 to 8 feet, and increases to 12 feet and more when the screens of the wells become clogged. One of the causes of this clogging of the screens is believed to be the large unit yields and the resulting high velocities of approach to the wells. This has been avoided in some of the ground-water plants abroad. (See Table 13.) The loss in entrance to the Tilburg wells is only one to two feet.

While the danger of clogging the stovepipe wells would be small because of the large perforations, it would be unwise to create velocities outside these wells that might continually draw in the fine sand and eventually destroy any pump that might be used. The probable velocity in the gross area of the gravels about the 16-inch stovepipe well during the above experiments, for a yield of 1,000,000 gallons daily, was about 800 feet per day. The actual velocities in the pore spaces of the gravel were, of course, greater than these figures. This greatly exceeds the ordinary rate of mechanical filtration, which ranges from 300 to 400 feet per day.

In order to keep down the velocities and minimize the losses of head, larger stovepipe wells should be adopted than those chosen for these experiments, and a larger proportion of the casing should be perforated, if the volume of 1,000,000 gallons each were to be drawn daily. The velocity of entrance for a well 24 inches in diameter, perforated for a length of 50 feet for this maximum yield, would be 420 feet per day, and the loss of head in the wall of the well would be only three to four feet. Ordinarily, only 700,000 or 800,000 gallons per day should be drawn from these wells, and the loss at entrance would be only two to three feet. By improving the perforator that has been used on these experimental wells, cuts could doubtless be made where the gravel is small and

scanty, and a greater length of screen section secured. Percolation experiments show that the sands containing too small an amount of gravel to permit of perforating with the tools now available, carry water quite as readily as the material in which perforations were made. The problem is to get the water into the well without the sand. It would hardly be possible, however, to perforate much over half the depth of the well, and the largest well that can be economically driven should be adopted.

It would be perfectly feasible to drive stovepipe wells 24 inches in diameter, or perhaps even larger, to the bottom of the yellow gravels, 100 to 200 feet below the surface, and this size is proposed for the Suffolk County works. The additional cost of driving these wells would not be proportionately greater than the smaller wells, and the added cost would be more than offset by the lower lifts and the smaller depreciation.

Another advantage in a larger well than those which have been experimented upon, would be a somewhat greater freedom from sand in the water pumped, because even should sand be drawn into a well by service pumping, the upward velocity would be insufficient to carry it up to the pumps and it would drop down to the bottom to be removed later.

Depth of Wells

The proposed wells should be driven only through the yellow gravels and stopped in a clay bed sufficiently below the deepest perforations to allow of some filling in at the bottom of the well without covering these perforations. A depth of 20 to 25 feet would probably be enough if the wells were pumped deeply and thoroughly cleaned out in the first place. Doubtless once a year it would be necessary to visit each well with a light sand bucket and a portable rig and remove the accumulations of sand at the bottom.

Extent of Influence of Pumping

The ground-water maps, Sheets 61, 62 and 63, Accs. 5589, 5590 and 5588, show roughly the extent of influence of the pumping in the surface of the ground-water at the experiment station. It appeared in Experiment 5 that Well 3 alone drew upon the southerly moving ground-water for a width of about 2,000 feet, when pumping on the average one million gallons per day, which corresponds to a draft of 500,000 gallons per day from each 1,000 feet of the line. When all three wells were

in operation, they apparently drew from a width of line about 3,800 feet. The average draft was 2.32 million gallons per day, which corresponds to a yield per 1,000 feet of 610,000 gallons per day. The above figures represent a very fair estimate of the amount of ground-water flow at the location of the experiment station, where the slope of the ground-water is less than 10 feet to the mile. Such figures should not, of course, be applied to the whole line because the yield per unit of length would be much greater in the vicinity of the streams.

Storage in Yellow Gravels

Studies of the yield and the volumes of the cones of depression indicate that these yellow gravels did not yield more than 10 or 15 per cent. of their total volume during any experiment. The storage draft can, however, only be approximated from these experiments, because of the amount of ground-water added to the surface of saturation by frequent rains. The pumping records indicate that the delivery of the three wells fell off in Experiment 6 from 2,800,000 on December 18, to about 2,000,000 on December 28, supposing the ground-water to be kept at approximately a constant hight after the first few days. The difference represents the draft on storage during these 11 days, and is estimated as a total volume of 6,000,000 gallons. The total volume of the cones of depression of the surface of the ground-water is estimated as 55,000,000 gallons, so that they yielded hardly more than 10 per cent. of their volume.

The sands and gravels have a pore space of 30 to 40 per cent. and experiments elsewhere on soil physics indicate that they might possibly yield in course of months, 30 per cent. of their gross volume. This figure is probably high, however, for ordinary storage computations, because in times of great demand it would not be possible to wait for the water bearing gravels to entirely drain. A delivery of the saturated strata of 20 per cent. is a much safer basis for estimates of storage in these yellow gravels on Long Island.

The explanation of this slow drainage of the water in the partially saturated sands is to be found in the small velocity of movement of water in capillary spaces. Some idea of this movement in partially saturated sands and gravels is seen in Plate VI, Appendix VII, following page 792 of the report of the Burr-Hering-Freeman Commission. It was estimated from this diagram that the larger portion of the percolation from the

heavier rains moving downward from the surface travelled at a rate of 0.5 foot to 3 feet per day, the larger rate corresponding to the greater percentage of moisture in the partially saturated gravels. Laboratory experiments and observations elsewhere show that this rate decreases with the dryness of the sands to 0.2 or even 0.1 foot per day, and it seems most probable that the last of the moisture left in the ground by the lowering of the water-table settled down at a rate approaching these figures.

PROPOSED WELL SYSTEM

On the basis of the experiments above described, it is proposed to design the well system as follows:

Type	California stovepipe wells
Size	24 to 30 inches in diameter, of hard steel gage No. 12
Depth	From 100 to 200 feet or more, being 20 feet below bottom of yellow gravels
Length of screen section	From 40 to 50 feet, depending on the depth and character of the gravel strata
Spacing	From 500 to 1,000 feet, according to character of water bearing strata and area or yield of watershed; average about 700 feet
Average yield	700,000 gallons per day from each well
Maximum yield	1,000,000 gallons per day from each well

Beyond Center Moriches, the depth of watershed is small, and the yield per mile of the collecting works would be less than in the westerly portion of the main line. For this easterly portion, 16-inch wells with an average yield of 300,000 to 400,000 gallons per day are proposed.

Table 25 shows the depths, spacing and yield of wells adopted in this report for the preliminary estimates of cost. The line is divided into sections of three to four miles each, in which it is proposed to operate the wells from central electric substations, as explained in the subsequent appendices.

TABLE 25

Preliminary Layout of Well System

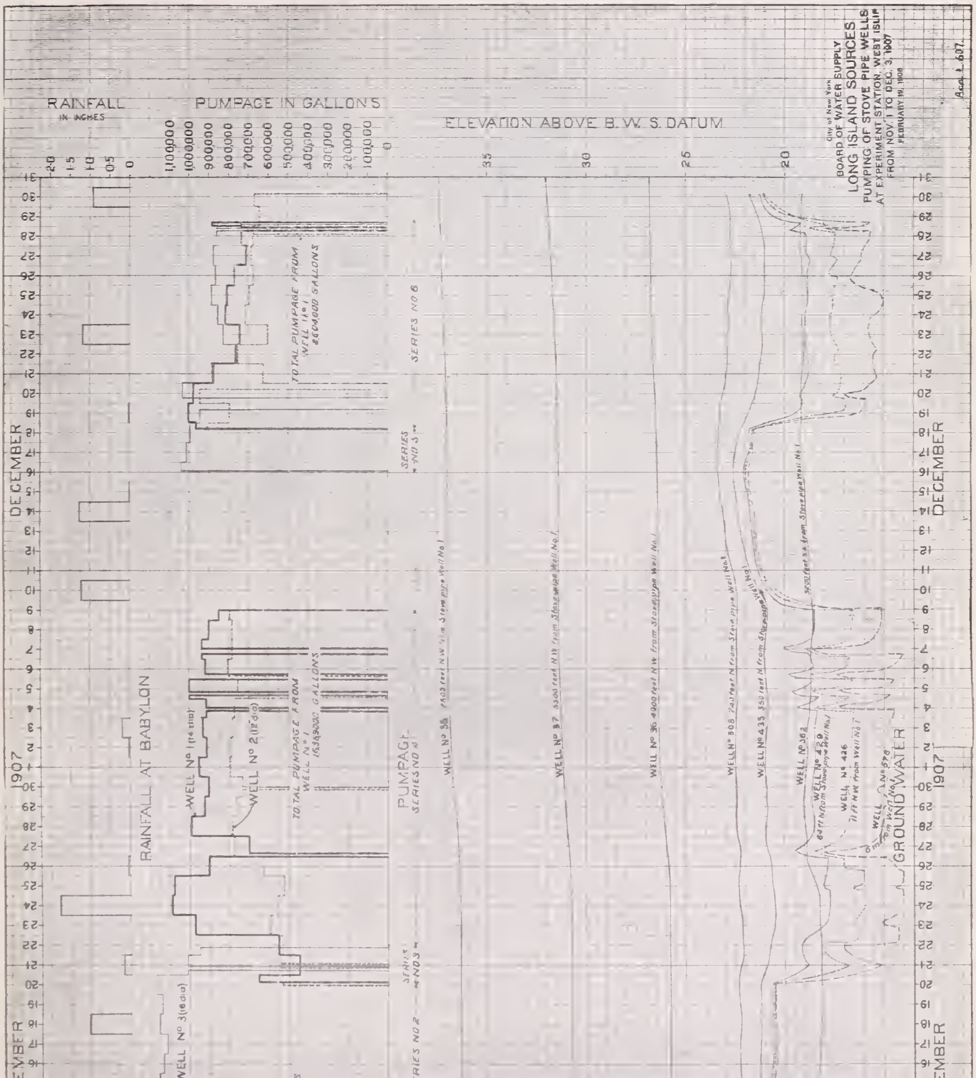
Section	Length of Section: From Station	Length of Section: To Station	Length of Section: Feet	Length of Section: Miles	Distance of East End of Section as Constructed at This Stage, in Miles from Ridgewood Pumping-Station	Size of Wells in This Section Inches	Number of Wells in This Section	Average Spacing of Wells Feet	Yield of Section Million Gallons per Day: Average	Yield of Section Million Gallons per Day: Maximum	Delivery of Each Well Gallons per Day: Average Pumpage	Delivery of Each Well Gallons per Day: Maximum Pumpage
SUFFOLK COUNTY LINE—24.48 MILES												
FIRST STAGE OF DEVELOPMENT TO GREAT RIVER, 14.7 MILES												
8	01 +36	194 +00	19,264	3.65	28.13	24	28	690	27	33	960,000	1,180,000
6	194 +00	406 +00	21,200	4.02	32.15	24	30	710	24	35	800,000	1,170,000
5	406 +00	660 +00	25,400	4.81	36.96	24	35	730	20	35	570,000	1,000,000
3	660 +00	777 +50	11,750	2.22	39.18	24	18	650	9	18	500,000	1,000,000
Totals and averages		....	**77,614**	**14.70**	....	**24**	**111**	**700**	**80**	**121**	**720,000**	**1,090,000**
ADDITIONAL DEVELOPMENT FOR SECOND STAGE TO SOUTH HAVEN, 14.8 MILES												
3	777 +50	884 +04	10,654	2.02	41.20	24	16	660	11	16	690,000	1,000,000
2	884 +04	184 +00	18,400	3.48	44.68	24	30	610	23	30	770,000	1,000,000
1	184 +00	405 +00	22,100	4.18	48.86	24	32	690	21	30	660,000	940,000
9	405 +00	610 +00	20,500	3.88	52.74	24	30	680	21	30	700,000	1,000,000
10	610 +00	677 +39	6,739	1.28	54.02	24	13	520	9	13	690,000	1,000,000
Totals and averages		....	**78,393**	**14.84**	....	**24**	**121**	**650**	**85**	**119**	**700,000**	**990,000**
ADDITIONAL DEVELOPMENT FOR THIRD STAGE TO QUOGUE, 18.9 MILES												
10	677 +39	774 +57	9,718	1.84	55.86	24	18	540	13	18	720,000	1,000,000
12	774 +57	965 +50	19,093	3.62	59.48	24	30	640	22	30	730,000	1,000,000
13	965 +50	1180 +00	21,450	4.07	63.55	16	30	710	12	20	400,000	670,000
14	1180 +00	1427 +00	24,700	4.68	68.23	16	35	710	12	20	340,000	570,000
15	1427 +00	1674 +00	24,700	4.68	72.91	16	35	710	12	20	340,000	570,000
Totals and averages		....	**99,661**	**18.89**	....	**24**	**48**	**600**	**35**	**48**	**730,000**	**1,000,000**
						16	**100**	**710**	**36**	**60**	**360,000**	**600,000**

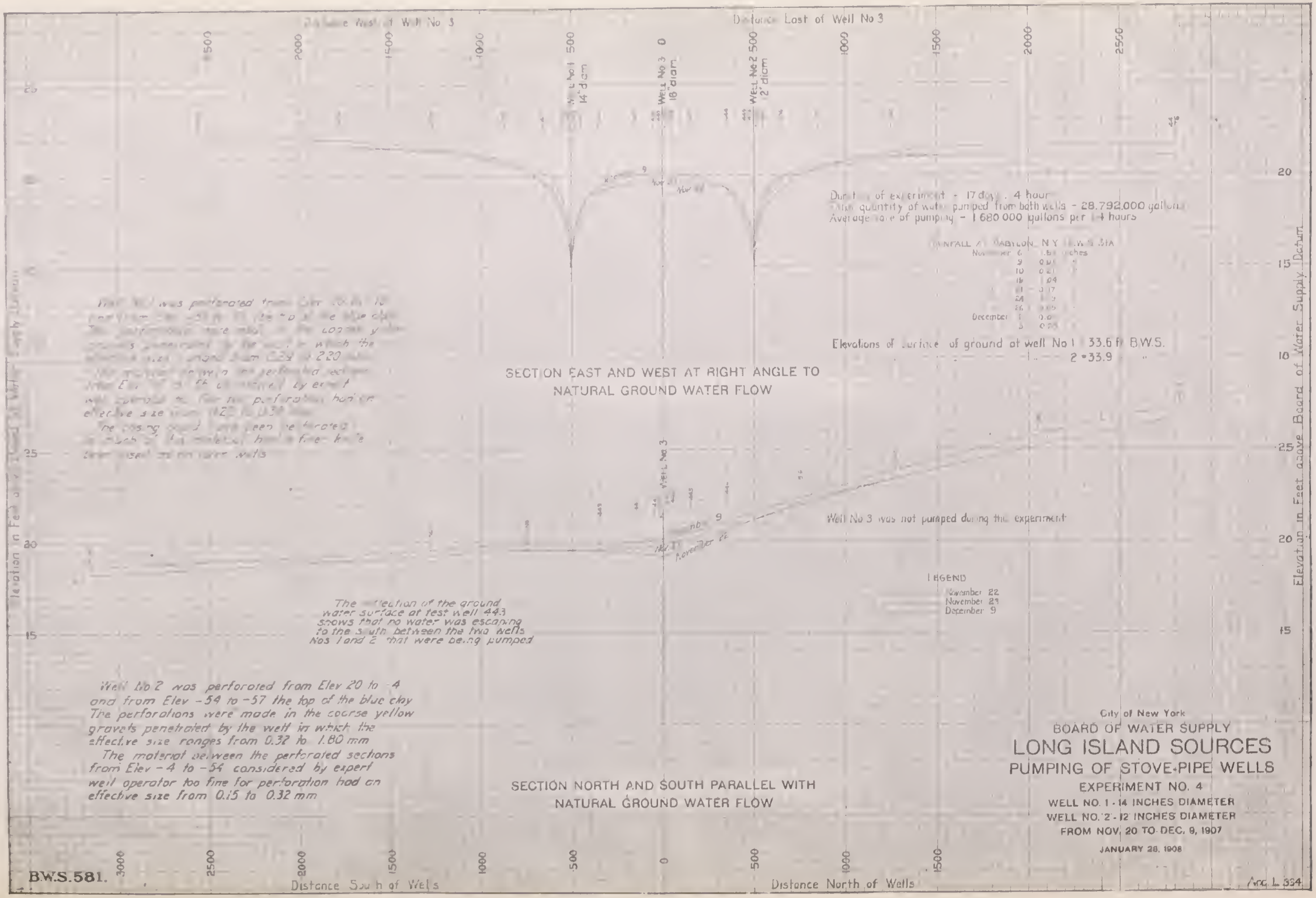
TABLE 25 (*Concluded*)

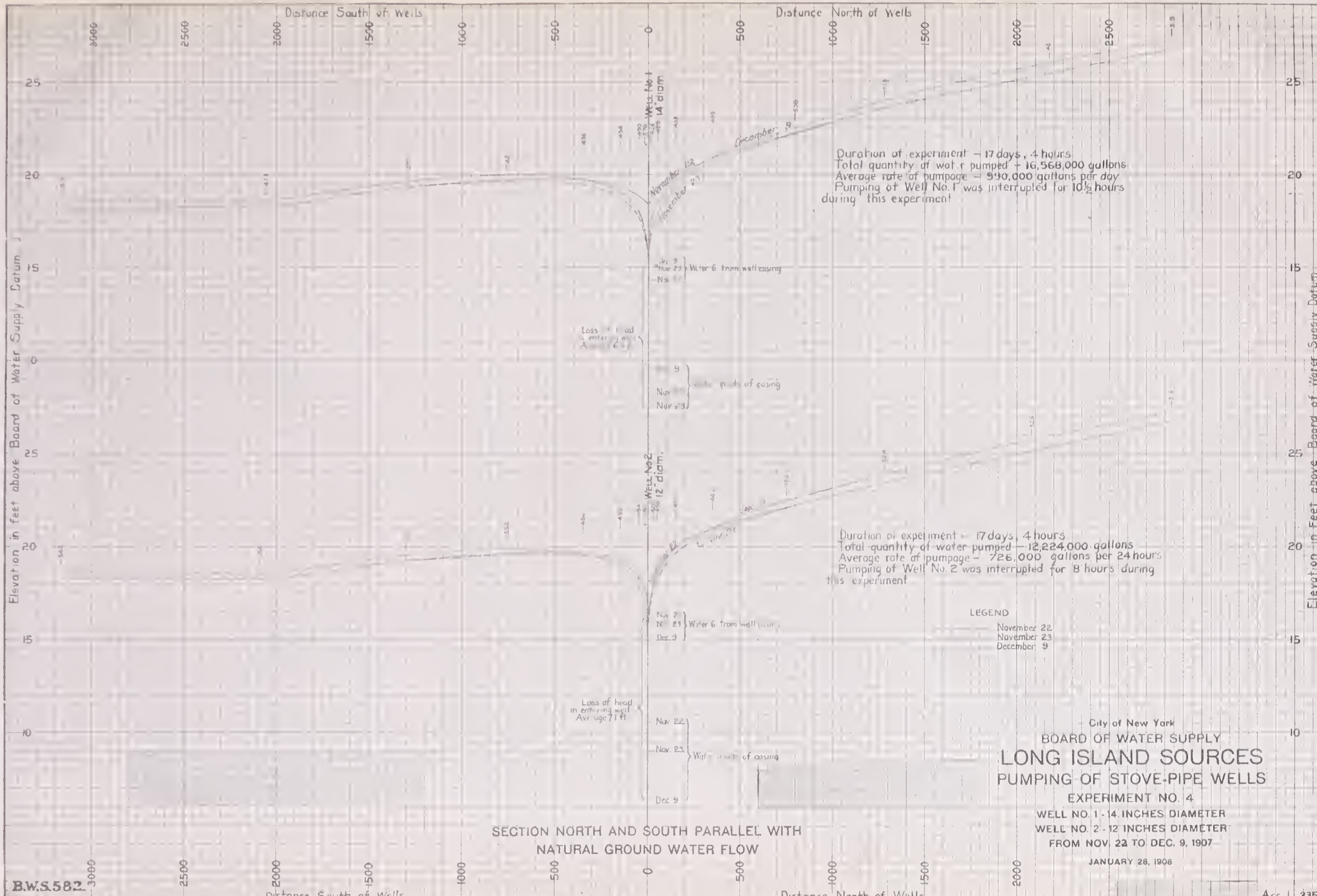
Section	Length of Section: From Station	Length of Section: To Station	Length of Section: Feet	Length of Section: Miles	Distance of East End of Section as Constructed at This Stage, in Miles from Ridgewood Pumping-Station	Size of Wells in This Section Inches	Number of Wells in This Section	Average Spacing of Wells Feet	Yield of Section Million Gallons per Day: Average	Yield of Section Million Gallons per Day: Maximum	Delivery of Each Well Gallons per Day: Average Pumpage	Delivery of Each Well Gallons per Day: Maximum Pumpage
ADDITIONAL DEVELOPMENT FOR FOURTH STAGE TO PECONIC VALLEY, 10.1 MILES												
					From main line							
16	(0=12+40)	320+00	30,760	5.83	5.83	..	..	...	..	..	......	....
	320+00	546+00	22,600	4.28	10.11	24	50	450	30	50	600,000	1,000,000
ADDITIONAL DEVELOPMENT FOR FIFTH AND LAST STAGE—BRANCH LINES, 24 MILES												
					Melville branch, 6.6 Miles From main line							
6	0	80+00	8,000	1.52	1.52	24	12	670	..	10	.....	830,000
7	80+00	350+00	27,000	5.11	6.63	24	40	670	..	40	......	1,000,000
Totals and averages			**35,000**	**6.63**	....	**24**	**52**	**670**	..	**50**	......	**960,000**
					Connetquot branch, 8.0 Miles From main line							
3	0	100+00	10,000	1.89	1.89	24	20	500	..	15	.....	750,000
4	100+00	420+00	32,000	6.06	7.95	24	52	620	..	35	......	680,000
Totals and averages			**42,000**	**7.95**	....	**24**	**72**	**590**	..	**50**	......	**700,000**
					Carman's branch, 9.4 Miles From main line							
10	0	113+00	11,300	2.14	2.14	24	25	450	..	18	......	720,000
11	113+00	494+70	38,170	7.23	9.37	24	54	710	..	32	......	600,000
Totals and averages			**49,470**	**9.37**	....	**24**	**79**	**630**	..	**50**	......	**630,000**

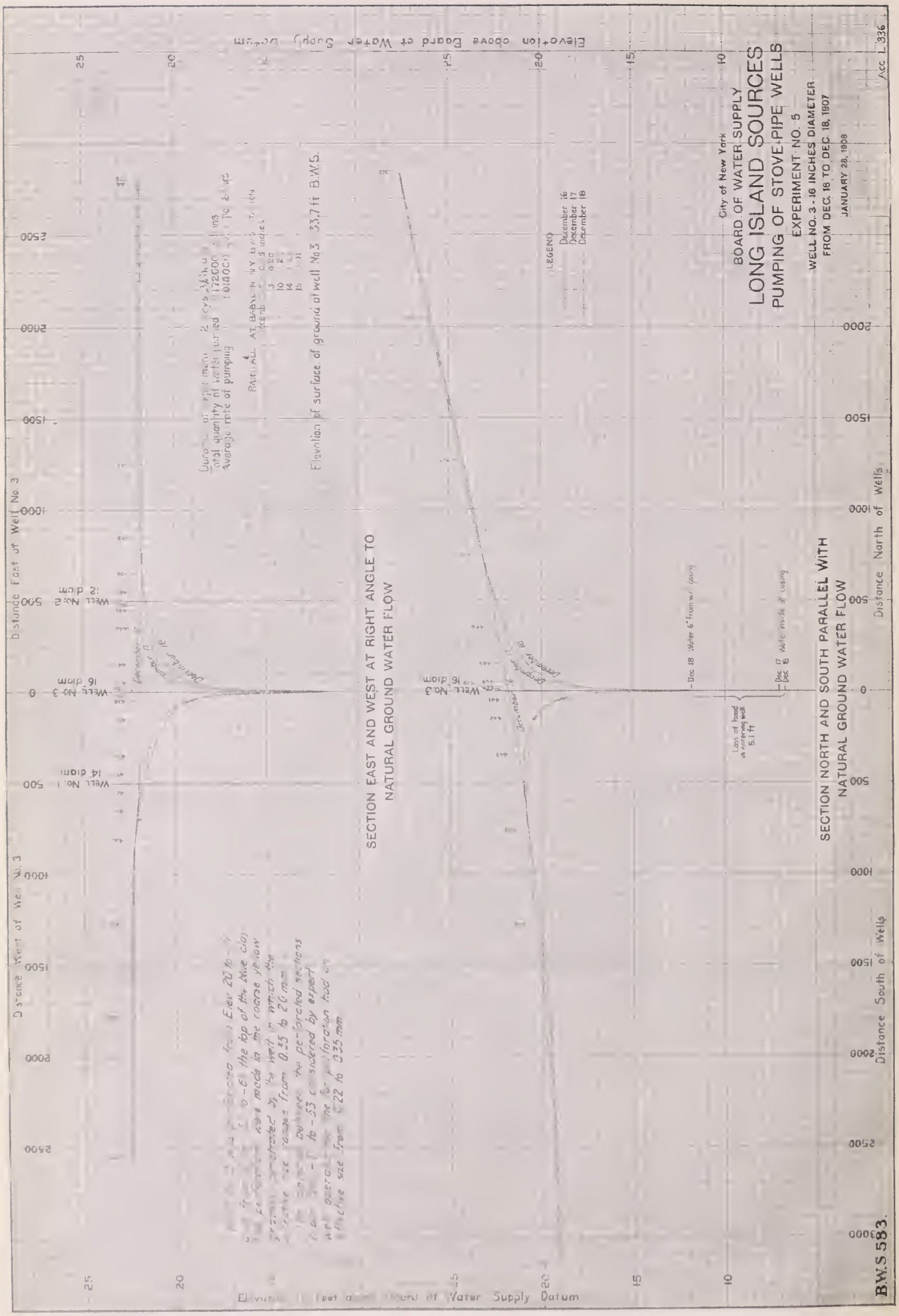

Stove pipe-wells, shown thus
2 inch test wells driven for ground water observations and designated by TW and serial number above convention, shown thus
Figures immediately below show the ground water elevation on December 16, 1908 before beginning of this experiment, figures below these the ground water elevation at end of this experiment December 28, 1907.
Where only one ground water elevation is shown it represents the ground water elevation on December 28, 1908.
Contours of surface of ground water on December 16, 1907 after an interval of seven days, during which there was no pumping, shown thus
Contours of surface of ground water on December 28, 1907 at end of pumping experiment Nº 6 On this date Wells Nos 1 and 2 had been pumped continuously for 10 days, and Well Nº 3 for 12 days, shown thus
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVEPIPE WELLS
EXPERIMENT NO. 6
WELL NO. 1 14-INCHES DIAMETER
WELL NO. 2 12-INCHES DIAMETER
WELL NO. 3 10-INCHES DIAMETER
FROM DEC. 18 TO DEC. 28, 1907
JANUARY 28, 1908
E. D. SAMMIS
MUNCY ROAD
ALFRED WAGSTAFF
SAMMIS ESTATE
Intermittent Pond
Swamp
LARRY GLYNN
J. S. PHINNEY
MACKIN
Old Road to Bayshore
MANOR LANE
19,200 N.
16,800 N.
187,200 E.
189,600 E.

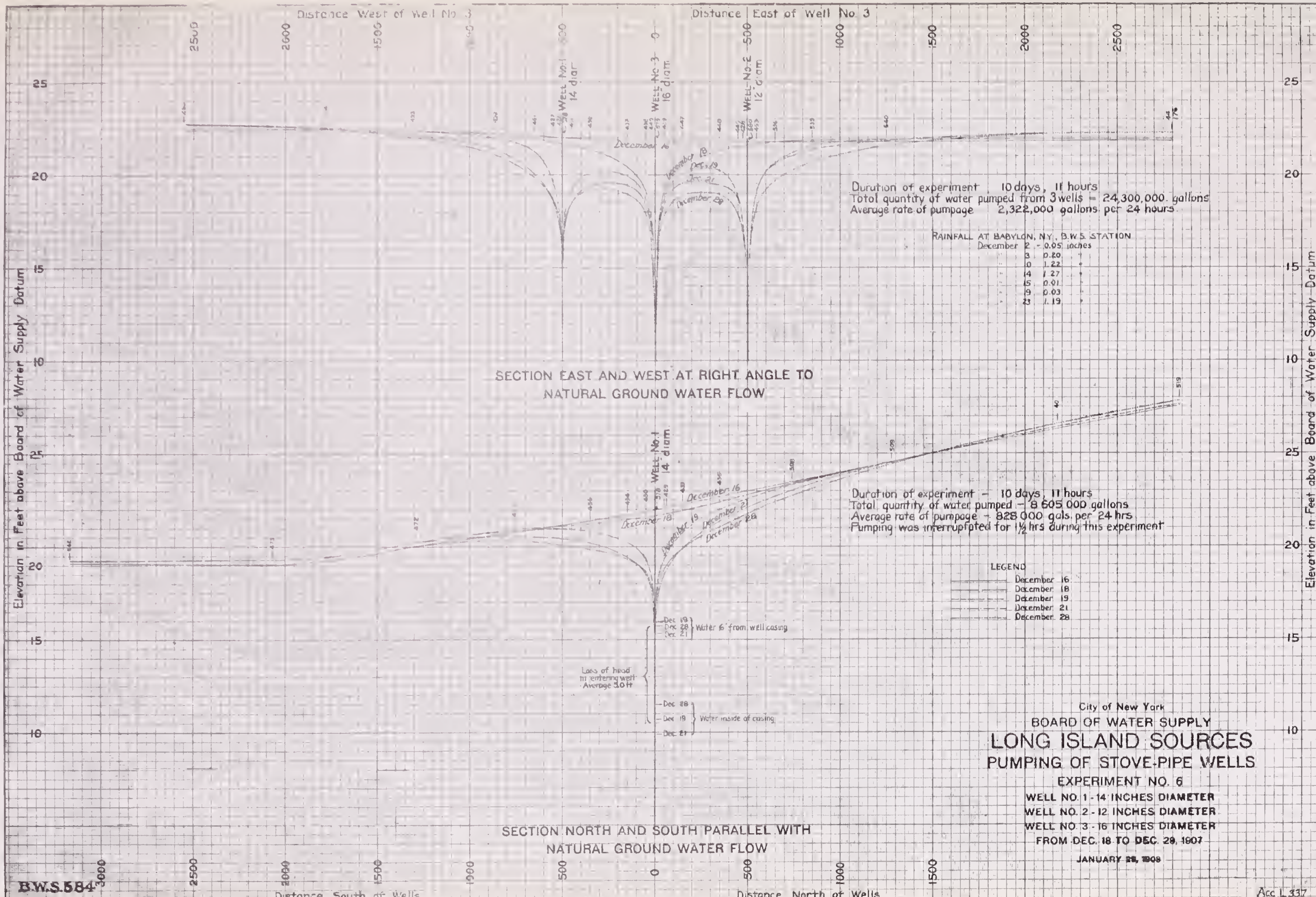
D.W.S. 671

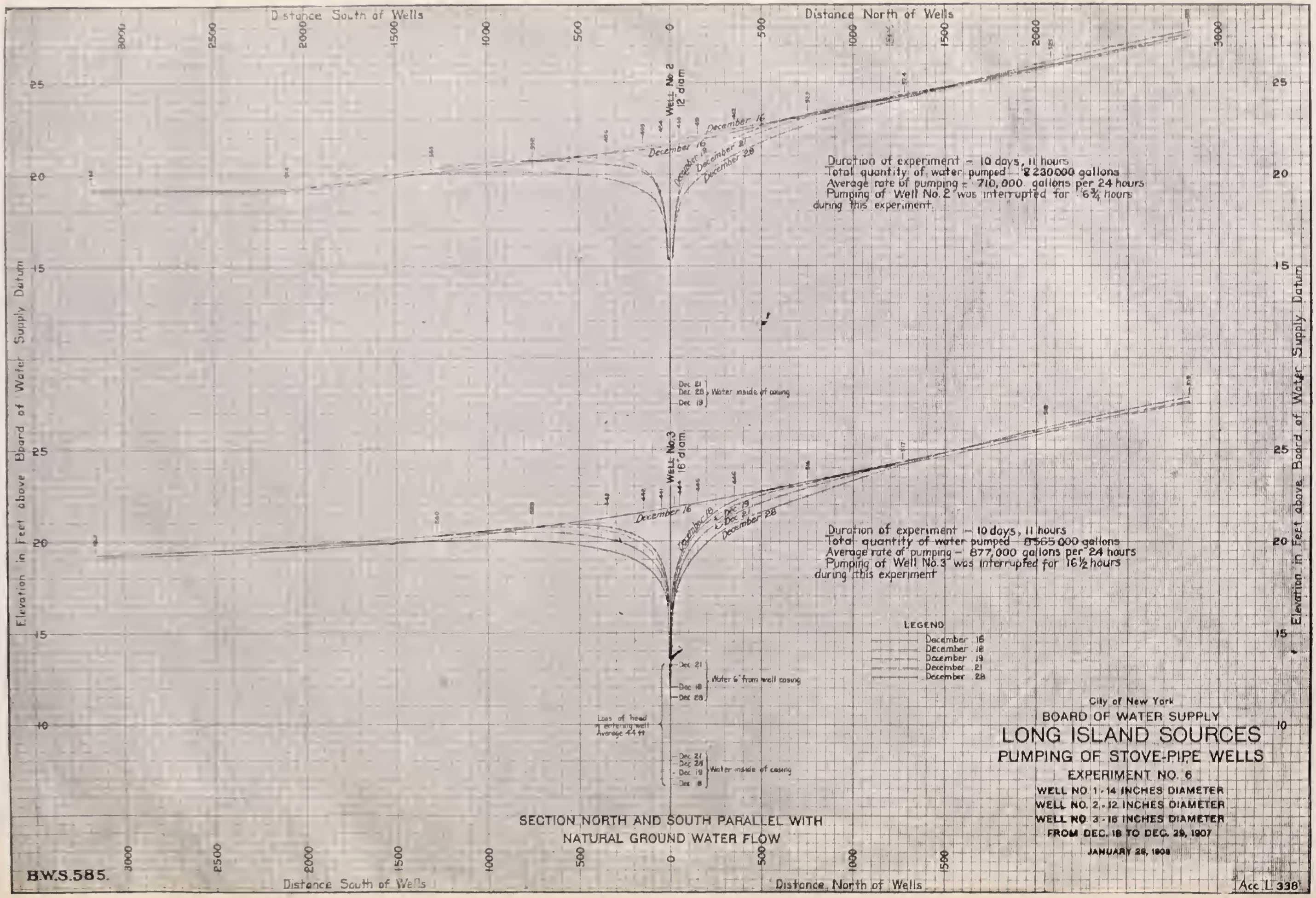

City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVE PIPE WELLS
AT EXPERIMENT STATION, WEST ISLIP
FROM NOV. 1 TO DEC. 3, 1907
FEBRUARY 19, 1908
RAINFALL
IN INCHES
PUMPAGE IN GALLONS
ELEVATION ABOVE B. W. S. DATUM
NOVEMBER
DECEMBER
1907
RAINFALL AT BABYLON
PUMPAGE
GROUND WATER
B.W.S. 590.


Distance West of Well No 3
Distance East of Well No 3
Well No 1 14" diam
Well No 3 18" diam
Well No 2 12" diam
Duration of experiment - 17 days, 4 hours
Total quantity of water pumped from both wells - 28,792,000 gallons
Average rate of pumping - 1 680 000 gallons per 24 hours
Elevations of surface of ground at well No 1 - 33.6 ft B.W.S.
2 - 33.9
SECTION EAST AND WEST AT RIGHT ANGLE TO
NATURAL GROUND WATER FLOW
Well No 3 was not pumped during the experiment
LEGEND
November 22
November 29
December 9
The reflection of the ground
water surface at test well 443
shows that no water was escaping
to the south between the two wells
Nos 1 and 2 that were being pumped
Well No 2 was perforated from Elev 20 to -4
and from Elev -54 to -57 the top of the blue clay
The perforations were made in the coarse yellow
gravels penetrated by the well in which the
effective size ranges from 0.32 to 1.80 mm
The material between the perforated sections
from Elev -4 to -54 considered by expert
well operator too fine for perforation had an
effective size from 0.15 to 0.32 mm
SECTION NORTH AND SOUTH PARALLEL WITH
NATURAL GROUND WATER FLOW
Distance South of Wells
Distance North of Wells
Elevation in Feet above Board of Water Supply Datum
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVE-PIPE WELLS
EXPERIMENT NO. 4
WELL NO. 1 - 14 INCHES DIAMETER
WELL NO. 2 - 12 INCHES DIAMETER
FROM NOV. 20 TO DEC. 9, 1907
JANUARY 28, 1908
B.W.S.581.
Acc. L 334


Distance South of Wells
Distance North of Wells
Elevation in feet above Board of Water Supply Datum
Well No 1 14" diam.
Well No 2 12" diam.
Duration of experiment - 17 days, 4 hours
Total quantity of water pumped - 16,568,000 gallons
Average rate of pumpage - 990,000 gallons per day
Pumping of Well No. 1 was interrupted for 10½ hours during this experiment
Duration of experiment - 17 days, 4 hours
Total quantity of water pumped - 12,224,000 gallons
Average rate of pumpage - 726,000 gallons per 24 hours
Pumping of Well No. 2 was interrupted for 8 hours during this experiment
LEGEND
November 22
November 23
December 9
Water 6 from well casing
Loss of head in entering well Average 7.1 ft
Nov. 22
Nov. 23
Dec 9
SECTION NORTH AND SOUTH PARALLEL WITH
NATURAL GROUND WATER FLOW
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVE-PIPE WELLS
EXPERIMENT NO. 4
WELL NO. 1 - 14 INCHES DIAMETER
WELL NO. 2 - 12 INCHES DIAMETER
FROM NOV. 22 TO DEC. 9, 1907
JANUARY 28, 1908
B.W.S.582.
Acc. L 335


City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVE-PIPE WELLS
EXPERIMENT NO. 5
WELL NO. 3 - 16 INCHES DIAMETER
JANUARY 28, 1908
SECTION EAST AND WEST AT RIGHT ANGLE TO NATURAL GROUND WATER FLOW
SECTION NORTH AND SOUTH PARALLEL WITH NATURAL GROUND WATER FLOW
Elevation of surface of ground at well No.3 33.7 ft B.W.S.
LEGEND
December 16
December 17
December 18
Loss of head in entering well 5.1 ft
Well No. 3 16 diam
Well No. 2 12 diam
Well No. 1 14 diam
Distance North of Wells
Distance South of Wells
Distance West of Well No. 3
Elevation above Board of Water Supply Datum
B.W.S. 583
Acc L 336


Distance West of Well No. 3
Distance East of Well No. 3
Well No. 1 - 500 14" diam
Well No. 3 - 0 16" diam
Well No. 2 - 500 12" diam
December 16
December 18
Dec. 19
Dec. 21
December 28
Duration of experiment, 10 days, 11 hours
Total quantity of water pumped from 3 wells = 24,300,000 gallons
Average rate of pumpage 2,322,000 gallons per 24 hours
RAINFALL AT BABYLON, N.Y., B.W.S. STATION
December 2 - 0.05 inches
3 - 0.20
10 - 1.22
14 - 1.27
15 - 0.01
19 - 0.03
23 - 1.19
SECTION EAST AND WEST AT RIGHT ANGLE TO
NATURAL GROUND WATER FLOW
Well No. 1 14" diam
Duration of experiment - 10 days, 11 hours
Total quantity of water pumped - 8 605 000 gallons
Average rate of pumpage - 828 000 gals. per 24 hrs
Pumping was interrupted for 1½ hrs during this experiment
LEGEND
December 16
December 18
December 19
December 21
December 28
Dec 19, Dec 28, Dec 21 Water 6" from well casing
Loss of head in entering well Average 3.0 ft
Dec 28, Dec 19, Dec 21 Water inside of casing
SECTION NORTH AND SOUTH PARALLEL WITH
NATURAL GROUND WATER FLOW
Distance South of Wells
Distance North of Wells
Elevation in Feet above Board of Water Supply Datum
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVE-PIPE WELLS
EXPERIMENT NO. 6
WELL NO. 1 - 14 INCHES DIAMETER
WELL NO. 2 - 12 INCHES DIAMETER
WELL NO. 3 - 16 INCHES DIAMETER
FROM DEC. 18 TO DEC. 28, 1907
JANUARY 28, 1908
B.W.S. 584
Acc L 337


Distance South of Wells
Distance North of Wells
Elevation in Feet above Board of Water Supply Datum
Well No 2
12" diam
December 16
December 19
December 21
December 28
Duration of experiment – 10 days, 11 hours
Total quantity of water pumped 8230000 gallons
Average rate of pumping – 710,000 gallons per 24 hours
Pumping of Well No. 2 was interrupted for 6¾ hours during this experiment.
Dec 21
Dec 28
Dec 19
Water inside of casing
Well No.3
16" diam.
Duration of experiment – 10 days, 11 hours
Total quantity of water pumped 8565 000 gallons
Average rate of pumping – 877,000 gallons per 24 hours
Pumping of Well No.3 was interrupted for 16½ hours during this experiment
LEGEND
December 16
December 18
December 19
December 21
December 28
Dec 21
Dec 18
Dec 28
Water 6" from well casing
Loss of head in entering well Average 4.4 ft
Dec 21
Dec 28
Dec 19
Dec 8
Water inside of casing
City of New York
BOARD OF WATER SUPPLY
LONG ISLAND SOURCES
PUMPING OF STOVE-PIPE WELLS
EXPERIMENT NO. 6
WELL NO. 1 - 14 INCHES DIAMETER
WELL NO. 2 - 12 INCHES DIAMETER
WELL NO. 3 - 16 INCHES DIAMETER
FROM DEC. 18 TO DEC. 28, 1907
JANUARY 28, 1908
SECTION NORTH AND SOUTH PARALLEL WITH
NATURAL GROUND WATER FLOW
B.W.S.585.
Acc L 338